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Assessment of bio-security knowledge, attitude and hygienic practices among smallholder chicken farmers in Southern Mozambique

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The production of broiler chickens in intensive systems struggles to maintain hygiene in production, despite contributing to combating malnutrition, generating employment, and increasing family income, especially in developing countries. Using a structured questionnaire survey, a cross-sectional study was carried out among 395 smallholder farmers to evaluate their knowledge, attitudes, and practices related to farm biosecurity in urban and peri-urban areas of Mozambique and determine the factors affecting KAP (knowledge, attitude, and practice) levels. Data were analyzed using Statistical Package for Social Science (SPSS) (IBM version 27). The findings indicate that education level and training significantly influence ($p < 0.001$) food safety in terms of biosecurity knowledge, attitudes, and practices. Smallholders who attended food safety training exhibited positive attitudes (95.5%, mean score of 89.71 ± 10.1) in contrast to those who did not participate in training (74.8%, mean score of 79.91 ± 9.68). Additionally, washing hands with soap before and after using the toilet and wearing protective clothing during chicken husbandry were significantly associated with education level ($\chi^2 = 15.345$, $P = 0.018$); those with informal education were 34% less likely to have a negative attitude toward food safety compared to those with high education. A significant correlation ($p < 0.01$) was observed between residence area, training, and biosecurity knowledge, attitude, and practice. Because smallholders lack training, hygiene expertise, and biosecurity practices on their farms, this study concluded that they pose a risk to public health and food safety. To maintain consumer health and guarantee food safety, farmers should properly dispose of waste, including dead chickens, and receive continuous training in excellent biosecurity measures on the farm.

Key words: Broiler chickens, smallholder farmers, food safety, KAP, biosecurity.

INTRODUCTION

Chicken is the main meat produced and consumed in many countries, especially in heavily populated urban and peri-urban areas (Alemneh and Getabalew, 2019; Goga and Roberts, 2023). In the world, especially in African nations, the production of poultry is a vital source of income and protein (Ahlers et al., 2009; Garsow et al.,

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2022 Chibanda et al., 2024). The global production of poultry meat has been growing gradually in 2021 it was approximately 121 million tons; in 2022 it was around 124 million tons and 2023 it reached 127 million tons (Food and Agriculture Organization Corporate Statistical Database (Faostat), 2025). Africa produced over 7.5 million tons of chicken meat in 2023, contributing about 5.9% of global production.

However, the global production of broiler chicken meat was estimated to be 103.5 million tons, and it is projected to increase to 104.2 million metric tons by 2024 (Shahbandeh, 2024). In low-income countries experiencing a food deficit, broiler chicken production increased by over 120% between 2000 and 2021. This expansion is justified by intensive production systems, urbanization, industrialization, rapid population growth, and genetic improvement of broiler chickens (El-Aziz et al., 2025). "Poultry" refers to domesticated birds valued for their meat and eggs, such as chickens, turkeys, ducks, geese, guinea fowl, pigeons, and quail (Nkukwana, 2018; Omondi, 2022). For commercial production of chicken meat, they are called "broiler chickens" (Cambaza dos Muchangos, 2012; Dien et al., 2023). The majority of poultry meat produced worldwide is broiler chicken (Mak et al., 2022; Mlambo et al., 2022).

Indigenous chickens are raised in rural and peri-urban settings, whereas broiler production has increased in urban areas due to population expansion, increasing chicken meat demand (Alemneh and Getabalew, 2019). According to da Conceição Nicolau et al. (2011) and Pym (2013) in Mozambique, the intensive or commercial system is dominated by the production of broiler chickens, with uniform stocks, raised in small quantities ranging from 100-500 per batch, for 35 to 42 days. In 2021 Mozambique produced 135,708 tons of broiler chickens' meat and a guaranteed supply of 98% of national consumption, with this production the country is self-sufficient in the production of broiler chicken (Mader, 2022).

In the country, the provinces of Maputo (south), Manica (center) and Nampula (north) lead broiler chicken production, with the province of Maputo leading production in the country. Additionally, the majority of broiler chickens are produced by smallholders, representing 70% of total chicken production (Cambaza dos Muchangos, 2012; da Conceição Nicolau et al., 2011). These are part of the informal group in the country's chicken production chain, raise broiler chickens by manually use family labor and are located in urban and peri-urban areas (da Conceição Nicolau et al., 2011). To ensure sustainable and profitable production in a chicken farm, farmers must properly implement vaccination programs against pathogens and engage in a biosecurity program to reduce the risk of introducing chicken pathogens (Food andAgriculture Organisation (FAO), 2007; Ravindran, 2013; Havelaar et al., 2022). Biosecurity is the primary strategy for disease control in intensive poultry production, which aims to reduce the risk of introduction, establishment and dissemination of diseases, infections or infestations in production or in the environment (Fathelrahman et al., 2020; Grace et al., 2024).

According to FAO (2007), Pym (2013) and Ravindran (2013), the biosecurity program for commercial poultry production sites consists of keeping chicken in a fully enclosed space, where the entry of other individuals is physically restricted, with only one access point, with a footbath equipped with disinfectant to preventing contamination. However, the introduction of infectious diseases into poultry farm is facilitated by the breach of biosecurity caused by human access into production. Farmers must also build bird netting to keep chicken away from pests and wild birds, in order to enable cleaning and disinfection, floors shouldn't be composed of earth, facilities shouldn't share equipment with one another, food and drink should not be contaminated by excrement, clean, closed containers are ideal for storing feed and the water supply should be decontaminated using chlorination to ensure healthy production (Amalraj et al., 2024; Pym, 2013; Ravindran, 2013).

Biosecurity programs involve quarantine of the production site, hygiene and disinfection, as a strategy to prevent the entry of diseases and contamination that could spread throughout the farm or country, affecting productivity, consumer health, food safety and the economy (Assefa, 2022; FAO, 2007; Ravindran, 2013). Biosecurity has many benefits, including increased productivity, improved global trade, enhanced public health, and environmental protection (FAO, 2007; Herrmann et al., 2024). Furthermore, biosecurity is the most important and crucial element of any strategy for avoiding and controlling poultry outbreaks and must be maintained at a high level in order to support the use of vaccinations (Assefa, 2022; Birhane and Fesseha, 2020; Fathelrahman et al., 2020; Tilli et al., 2022). Developing countries rely too heavily on vaccinations to control chicken diseases, rather than enhancing biosecurity to prevent disease introduction and ensure food safety (Birhane and Fesseha, 2020; Grace et al., 2024; Pym, 2013). This makes it simple for harmful microorganisms to infiltrate production, forcing farmers to use antibiotics and vaccinations (FAO, 2007; Pao et al., 2023; Ravindran, 2013).

In order to prevent infectious diseases, smallholder farmers with limited resources should follow these easily accessible and effective biosecurity guidelines: clean the chicken farm and utensils on a regular basis, provide separate housing for broiler chickens ages, vaccinate appropriately, keep the broiler chickens breeding area away from humans and other animals, regularly clean and dispose of manure and compost it for three weeks, throw away sick and dead animals and clean, decontaminate, disinfect infected materials. Avoid introducing new chicks of unknown origin (FAO, 2007; MacPhillamy et al., 2022;

Pym, 2013). Cages should always be cleaned with soap or disinfectant and let it dry before being brought to the farm (Assefa, 2022; FAO, 2007; 2013). If they do not have disinfectant, they should use a closed black plastic bag that is exposed to direct sunlight for a day in order to inactivate the microbes that cause the disease. They should also wash their hands with soap after handling chickens.

Despite significant government investment in food safety, diseases caused by biological hazards associated with food and the failure of biosecurity measures are widespread and up to one-third of population are affected by foodborne microbial diseases each year, the majority of which are zoonotic pathogens (FAO, 2007; Adjei-Mensah et al., 2024; Amalraj et al., 2024). Disease outbreaks in poultry farms can be significantly worsened without proper biosecurity measures, which is particularly important for smallholder producers who often face limitations in infrastructure and resources. Smallholder poultry farming is an important economic and nutritional driver in Sub-Saharan Africa, thus it is critical that the region adopts biosecurity measures to protect its citizens' well-being and the economy (Ahlers et al., 2009; Azabo et al., 2022). Studies indicate that smallholder chicken producers in Africa recognize the importance of biosecurity; however, their comprehension is frequently inadequate and not consistently implemented. A study in Ghana indicated that farmers recognized the significance of biosecurity protocols; however, they encountered difficulties in consistently implementing these measures due to various constraints (Buckel et al., 2024). Otieno et al. (2023), found that farmers in Kenya were more likely to implement strict biosecurity measures when they had access to biosecurity information. The implementation of biosecurity measures among smallholder broiler producers is often insufficient and inconsistent. A study conducted in Tanzania's Pwani region indicated that while farmers acknowledged the significance of biosecurity, their application of related practices was moderate, as evidenced by an average Biosecurity Index Score of 53.83% (Gomez and Mbaga, 2023). In Egypt, small-scale poultry producers rarely implemented standard biosecurity measures, resulting in the identification of considerable risk practices, such as the improper disposal of poultry carcasses (Negro-Calduch et al., 2013).

Several factors influence the adoption and implementation of biosecurity practices or measures among smallholder chicken producers have been documented. According to Khalil et al. (2023) and Pym (2013) developing countries face challenges due to sub optimal housing conditions and lack of quality feed, vaccines and trained staff. Intensive chicken production systems are a source of environmental pollution, facilitating the dissemination of infectious diseases due to the accumulation of waste bedding, fecal-contaminated wastewater, feed, feathers, medications, and moisture, which promotes mite proliferation, unpleasant odors, and greenhouse gas emissions, particularly when Good Hygiene Practices (GHP) are not adhered (Muduli et al., 2019; Singh et al., 2018). Pathogenic microorganisms such as *Salmonella*, *Escherichia coli*, *Campylobacter*, and *Staphylococcus aureus* can induce rapidly spreading diseases on farms, diminishing output and impacting both the economic and public health. These bacteria cause diseases with high morbidity and mortality in chicken production, with emphasis on colibacillosis, salmonellosis (fowl typhoid, pullorum), enteritis, bacteremia, gangrenous dermatitis, septicemia, arthritis, omphalitis and bumblefoot (Halder et al., 2021; Hassan, 2024).

Olutumise et al. (2023) reported that farmers in Nigeria incur economic losses from disease outbreaks attributable to inadequate biosecurity measures and limited access to veterinary services. Insufficient surveillance, inadequate biosecurity in broiler chicken production, and the absence of laboratory diagnostics facilitate the emergence of harmful infections in broiler chicken production (Bedekelabou et al., 2022; Kalam et al., 2022; Khalil et al., 2023).

Healthy broiler chicks need a clean environment and housing to minimize parasites, dust, and microbiological contamination, as well as worms, flies, and waste and manure management. Smallholders have inadequate resources for minimum biosecurity measures, such as quarantining chicks, disinfecting utensils, and limiting visitors, outside equipment, animals, and pests (Islam et al., 2024). Biosecurity in production is the precautionary measures for disease outbreak (Amalraj et al., 2024; Khalil et al., 2023; Olutumise et al., 2023; Siddiky et al., 2022). However, studies on KAP regarding biosecurity are limited in developing countries (Kalam et al., 2022; Mudenda et al., 2022).

To promote food safety and protect consumers from food-borne illnesses and poisoning, it is essential to comprehend KAP about biosecurity (Biswas et al., 2024). This study was developed to evaluate the knowledge, attitude and practices of smallholder farmers in relation to biosecurity in the Southern Region of Mozambique. The results of this study will bring more information about knowledge, attitude and practice on biosecurity in broiler chicken production, initiatives for raising healthy chickens and suggestions for interventions necessary to reduce the threat of outbreaks.

MATERIALS AND METHODS

Study area

The study was conducted in three provinces of southern Mozambique (Maputo, Gaza, and Inhambane) involving poultry farmers breeding broiler chickens in the districts of KaNhamakulu, KaMavota, KaMubukwana, Xai-Xai and Massinga (Figure 1). These regions were chosen because have large concentration of chicken farming (Cambaza dos Muchangos, 2012; da Conceição Nicolau et

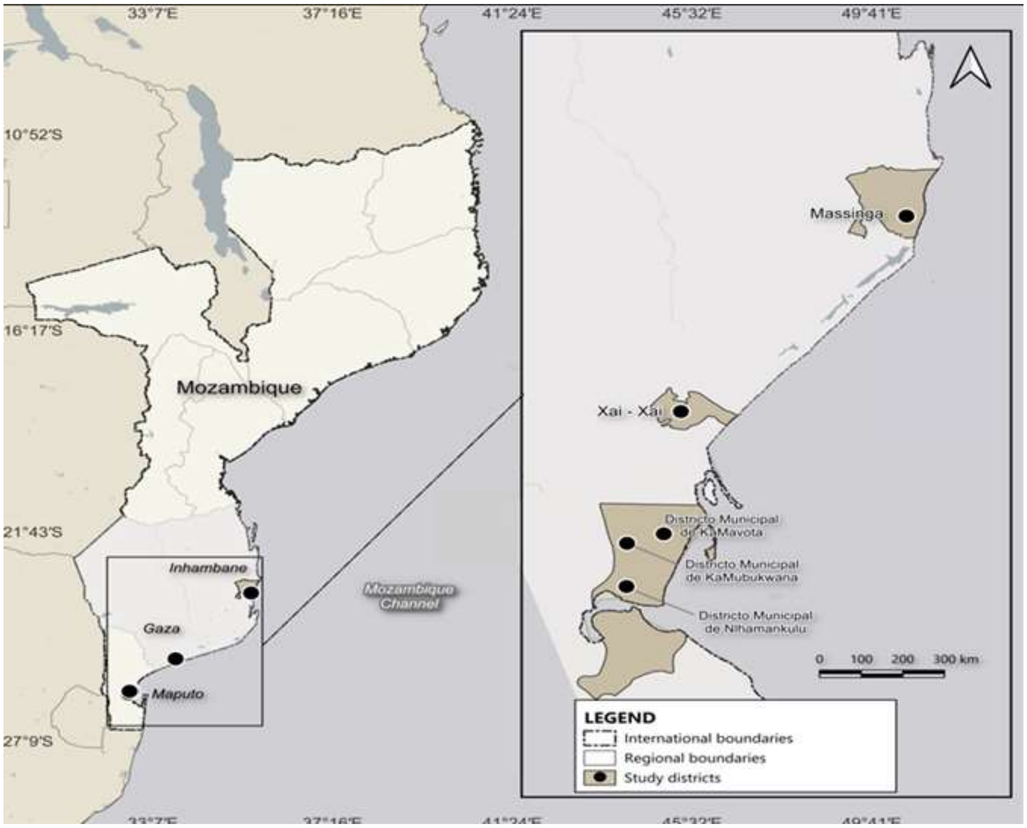

Figure 1. Map of study area.

al., 2011).

Identification of districts and smallholder farmers

Prior to data collection, the National Directorate of Animal Health provided a list of producers and two field assistants. The Directorate of Commerce was contacted and provided the list of districts. Mozambican Poultry Farmers Association (AMA) was contacted in order to gather an additional list of farmers. With the guidance of field assistants and members of the AMA, areas were particularly chosen based on already established farms, the intensive production of broiler chickens, the diversity of broiler production areas, and smallholders who kept broiler chickens on their farms for commercial purpose were randomly selected. The districts and farmers' locations for the data collection phase were then compiled. In order to prevent bias in survey results who were veterinarians and industrial farmers were not included in the study.

Study design and sample size

A cross-sectional study design was employed to conduct a smallholder farmer’s survey, between October 2023 to April 2024. With a 95% confidence interval, 5% margin of error, and the assumption that 50% (p = 0.5) of producers have positive knowledge, attitudes, and practices regarding biosecurity measures, a single proportion estimate was applied using Cochran's formula for large populations or unknown populations to determine the necessary sample size. Although 384 farmers were the minimal sample size needed, however, to gather enough data from five different sites, for possible incomplete responses and to boost the significance of the findings, 402 smallholder farmers participated in the current field survey, of which 395 were completed.

Data collection tools

A structured questionnaire and checklist were used for collect data. The KAP questionnaire with closed-ended questions about socio-demographic characteristics and bio-security were developed in English using information obtained from similar studies (Bedekelabou et al., 2022; Khalil et al., 2023). Questionnaire was translated into Portuguese (national language in Mozambique), and depending on the farmer's educational background, the interviews were conducted in either Portuguese or their local language (Xitsonga, Xichangana, or Xitswa). Observational data on biosecurity use compliance in farms areas was recorded using the checklist.

The questionnaires' primary objectives were to gather sociodemographic data (gender, age, marital status, education, experience in chicken production, residence area, training course, land ownership, employment status, availability of electricity and toilet facilities), farm and farmer characteristics (holding a chicken production course, registering with the broiler producers' committee, production system, farmer's source of income, number of broiler chickens in production, mortality level per cycle, farm inspection and its regularity), and data regarding the current level of biosecurity knowledge, attitudes and practices (explained below) in broiler production in the study region.

In Mozambique, poultry is raised everywhere, and biosecurity standards range from reasonable to poor (FAO, 2013). The predominant production system is family poultry farming (extensive system), where chickens roam freely, mixing with other animals. Another expanding production system is small-scale intensive farming, where broiler chickens are fenced and fed for commercial purposes. Biosecurity is the main strategy to prevent disease in broiler chickens' production, although smallholder farmers in developing countries lack the adequate biosecurity measures because to their limited resources (Grace et al., 2024; Pym, 2013).

Pilot test

The questionnaire was pre-tested during which the reliability of the questionnaire instrument and the checklist was verified (Khalil et al., 2023; Pao et al., 2023). The questionnaires were validated for clarity of questions, consistency in responses provided, time taken to complete the questionnaire, and type of data received for analysis. The revised questionnaire was then used for data collection (Nkosi and Tabit, 2021). A panel of experts in food security from Sokoine University of Agriculture's, Department of Food Science and Agro-Processing, guaranteed content validity by assessing the questionnaire and checklist for suitability and relevance to the study's objectives.

Following instrument validation, the principal investigator visited to the selected districts at different times of day with trained AMA members and field assistants. Informed consent was obtained from each participant prior to each interview; the purpose of the study was explained to the farmers to obtain their verbal consent. Through face-to-face interviews lasting approximately twenty-five minutes per session, while each observation session lasted approximately ten minutes were used to collect the information.

Evaluation of biosecurity knowledge of smallholder's chicken farmers

The methodology of previously published investigations was used to develop KAP (Bedekelabou et al., 2022). In the demographic information, smallholder farmers were inquired about the age, gender, civil status, education level, and years of practice experience, residence area and any biosecurity training in the chicken production. A total of fifteen questions were created in order to evaluate smallholders' knowledge about biosecurity in chicken production (personal hygiene, cross contamination, cleaning and disinfection of equipment, washing and disinfecting contact surfaces, knowledge of food borne pathogens, clean litter, etc.). The knowledge question each with two possible answers "yes and no" was coded as 1 and 0 (Yes =1 for good knowledge or correct answers and No = 0 for poor knowledge or wrong answers).

In intensive broiler production, bacterial diseases such avian salmonellosis, campylobacteriosis, fowl cholera, and avian colibacillosis are thought to be the main causes of morbidity and mortality (FAO, 2007; Grace et al., 2024).

Additionally, they may result in lower productivity. Outbreaks of human foodborne diseases are mostly caused by toxigenic colibacillosis, campylobacteriosis, and non-typhoidal salmonellosis, with broiler chickens serving as a major reservoir (Havelaar et al., 2015, 2022; Li et al., 2019). To improve biosecurity practices, it is essential to ensure that farmers understand disease processes and believe that infectious agents are the cause of diseases (Ahlers et al., 2009; Pym, 2013) In this study, we also examined producers' knowledge related to biosecurity measures in broiler chickens' production, including the awareness about pathogens such as *Salmonella*, *Campylobacter*, *E. coli*, and *S. aureus*.

According to a report on major zoonotic broiler chicken diseases in sub-Saharan Africa, campylobacteriosis is most widespread in Central Africa (91%), followed by Eastern, Southern, and Western Africa, and salmonellosis is most common in Southern Africa (28%) (Thomas et al., 2020). Mozambique only produced one study on campylobacteriosis.

According to a report, 90% of farms in Mozambique do not follow biosecurity measures to prevent diseases from entering and spreading (Chunga et al., 2025; Fabret, 2007; FAO, 2013). Footbaths are absent from about 81% of farms, and where are present, there is no disinfection (Fabret, 2007; FAO, 2013). Approximately 78% of farmers lacked laboratory support to identify the cause of why chickens died. In this survey, no farmer reported receiving laboratory assistance in the event that a broiler chicken died, and over 90% of farms lacked footbaths.

Evaluation of smallholder chicken farmers' biosecurity attitude

The questionnaire on attitude was intended to obtain information on the personal hygiene and food borne diseases; importance of bio-security training; safe chicken production and the importance of personal hygiene; foodborne diseases and human health, washing drinking fountains and feeders with treated water prevent contamination; contaminated water can cause diseases; protect feed and water from contaminants; dispose of waste carefully, footbath, decontaminating and disinfecting the chicken farm reduces contamination; wearing protective equipment and separation of sick chickens is important to reduce contamination. 12 questions were created with three answer options were designated as 2, 1, and 0 (2 = strongly agree, 1 = agree, and 0 = disagree). Scores ranged from 0 to 18 and 100 points were applied to the scores. Smallholder farmers in Africa face challenges, due to high levels of diseases, inadequate sanitation and biosecurity measures that allow infections to spread, poor feed and water quality, a lack of veterinary assistance and diagnostic tools, and a lack of resources to implement biosecurity (Adesola et al., 2025; Grace et al., 2024). Additionally, a lot of smallholder farmers do not have the resources or insufficient knowledge, attitude and practices to implement appropriate biosecurity measures (Grace et al., 2024; Imam et al., 2021).

A study conducted in Belgium revealed a positive correlation between educational level and good attitudes toward appropriate biosecurity measures. Producers with higher education demonstrated a better understanding and willingness to apply biosecurity standards, as evidenced by significantly higher attitude scores ($p < 0.01$) compared to those with less education (Amalraj et al., 2024). Taiwanese study found that although farmers had a favorable attitude toward biosecurity, they did not implement the recommended biosecurity practices. According to farmers, a lack of resources is one of the challenges farmers faces when implementing biosecurity measures on their farms (Pao et al., 2023).

Evaluation of smallholder chicken farmers' practices on bio-security

Eight questions were employed to assess the practices of smallholders, with three response options: 2 = always, 1 = sometimes, and 0 = never. KAP scores were converted to a scale of 100 points. Hygienic practices, handling chickens with care, wearing protective clothes during chickens rearing, working while sick, clean and disinfect all farms before and after production, wash hands with soap, washing and sanitizing the clothes and utensils before and after feeding the chicken were evaluated in this section. A score <50 was considered as an poor level, scores ranging from ≥50 to <75 were designated as medium and scores ≥75 were considered as a good level of knowledge, attitude and practice of bio-security in chicken production (Ahmed et al., 2024; Hossen et al., 2020).

According to similar study, biosecurity measures on broiler chicken farms in Bangladesh, the majority of farmers clean or disinfect the farm's surfaces and equipment once a week (87.6%), separate sick from healthy chickens (56.7%), use systematic washing facilities before entering a farm (57.7%), dispose of manure safely (56.2%), change clothes and shoes before entering the farm (16.1%), and have footbath (20.2%) (Imam et al., 2021).

Ethical clearance

A permit for research was requested from the Vice Chancellor of Sokoine University Agriculture (SUA), Tanzania and conduction of research was approved by the Directorate of Postgraduate Studies, Research, Technology Transfer and Consultancy (DPRTC) of SUA. The study was further approved by the National Directorate of Animal Health of Mozambique (reference: number 1635/SAECM/DAP/ 11/23). After the smallholder farmers were informed of the purpose of the study, each participant provided their verbal and informed consent before to each interview. Participants received assurances of confidentiality and anonymity throughout the data processing procedure.

Statistical analysis

The data were analyzed using SPSS version 27. Demographic characteristics data were summarized using categories and descriptive statistics (standard deviation and mean frequency). Chi-square tests were employed to determine relationship between categorical variables, while regression analysis was conducted to assess the effects of various factors on food safety knowledge, attitudes, and practices. Analysis of Variance (ANOVA) was performed to examine differences among groups as observed in the regression analysis and P-value with $P \leq 0.001$ were considered highly significant and $P \leq 0.05$ as significant.

RESULTS

Socio-demographic characteristics of smallholder chicken farmers

The socio-demographic characteristics of chicken farmers are presented in Table 1. It was revealed that most producers are concentrated in the Maputo Province (76.7%) and smaller portion of producers operate in the Inhambane (10.9%) provinces. The producers (71.4%) have not attended any training on food safety regarding biosecurity. A majority (80.5%) own land, and most have access to electricity (82.0%), which supports efficient chicken production activities. Sanitary conditions are generally adequate; with 83.0% having access to sanitary toilets with water, though a small portion still uses open spaces or basic pit latrines and 81.3% are farm owners, suggesting a high level of commitment and investment in the sector.

Characteristics of respondents' and chicken production facilities

Table 2 presents characteristics and income sources of smallholder farmers. A vast majority (92.4%) do not hold any specific course on broiler chicken husbandry, with only 7.6% having such qualifications, indicating a gap that could impact bio-security practices. Almost (85.6%) of chicken production facilities are not authorized by local authorities, indicating a widespread lack of formal recognition and regulatory oversight. Conversely, low producers (10.4%) are registered with a Chicken Producers Commission. Chicken production serves as the main income source for 73.2% of respondents. Despite the predominant reliance on intensive farming systems (100%), which typically require specific skills and knowledge? The majority of farmers had a flock size between 50 to 500 chickens (82.3%), and the most common mortality rate is under 20%. Inspection by livestock service occurs less frequently, with 54.4% of facilities never having been inspected. Farmers received inspections, semiannually (82.8%) and an annual inspection about (6.9%) inspections. Additionally, a notable 27.6% of farmers had received penalties for non-compliance, highlighting ongoing challenges in adhering to hygiene regulations.

Evaluation of smallholder chicken farmers' bio-security knowledge

The bio security knowledge of smallholder chicken farmers across different districts, are presented in Table 3. Nearly all respondents (98%) recognize the importance of washing hands with detergent/soap and warm water (item A), with no significant difference across districts ($\chi2$ = 7.037, P = 0.134). Substantial variations were noted in other areas, for instance, 90.6% recognize the necessity of hand washing after utilizing the restroom (item B), although this awareness markedly differs among districts ($\chi2$ = 48.382, $P < 0.001$), revealing disparities in areas such as KaMavota (78.4%) and Massinga (76.7%). Knowledge regarding wearing protective clothes is high (93.4%) but varies significantly ($\chi2$ = 18.669, P = 0.001). There was notably less awareness regarding avoiding caring for chickens with bare hands, with only 48.4% knowledgeable, showing significant district variation ($\chi2$ = 72.862, $P < 0.001$). Awareness regarding avoiding working when sick was lower (41%) with significant differences ($\chi2$ = 45.102, $P < 0.001$), indicating the need for extension and training programs. Despite the acknowledged (81%, item F) that appropriate instruments handling, cleaning, and disinfection can reduce cross-contamination, there were significant variations in district-to-district compliance ($\chi2$ = 27.687, $P < 0.001$), suggesting potential problems, particularly in KaMavota (53.2%). Finally, understanding the importance of sanitizing work tools is high (93.9%) but still varies significantly ($\chi2$ = 41.625, $P < 0.001$).

Table 4 provides insights into bio-security knowledge regarding cross-contamination among chicken farmers in different districts. Almost all producers recognize the

Table 1. Socio-demographic characteristics of smallholder chicken farmers.

Variable	Category	Frequency	Percentage
Gender	Female	237	60.00
	Male	158	40.00
Age of respondent	Less than 20 years	22	5.60
	20-40 years	129	32.70
	41-60 years	210	53.20
	Above 60 years	34	8.60
Marital status	Married	185	46.80
	Unmarried, living with a partner	123	31.10
	Unmarried, living without a partner	58	14.70
	Separated	15	3.80
	Divorced	1	0.30
	Widowed	13	3.30
Education level	High school level (Over 12)	62	15.70
	Secondary school level (grade 7-12)	238	60.30
	Primary school level (grade 1-6)	53	13.40
	No formal education	42	10.60
Experience in producing chickens	Less than 5 years	47	11.90
	5-9 years	153	38.70
	10-20 years	137	34.70
	More than 20 years	58	14.70
Residence area	Peri-urban	303	76.70
	Urban	92	23.30
In which Province do you produce chickens?	Maputo	303	76.70
	Gaza	49	12.40
	Inhambane	43	10.90
In which District do you produce chickens?	KaNlhamakulu	87	22.00
	KaMavota	111	28.10
	KaMubukwana	105	26.60
	Xai-Xai	49	12.40
	Massinga	43	10.90
Have you ever attended a training course on food safety regarding bio-security?	No	282	71.40
	Yes	113	28.60
If yes, when last did you attend the bio-security training?	Less than 5 months	44	38.90
	Between 6 months and 1 year	40	35.40
	More than 1 year	29	27.70
Do you have land ownership?	No	77	19.50
	Yes	318	80.50
Do you have any other employment?	Full time	45	11.40
	Part time	29	7.30
	Farm owner	321	81.30
Electricity facilities	No electricity/No solar	38	9.60
	Solar	33	8.40
	Electricity/Charcoal	324	82.00

Table 1. Contd.

Variable	Category	Frequency	Percentage
Toilet facilities	Open space	21	5.30
	Pit latrine	23	5.80
	Sanitary without water seal	23	5.80
	Sanitary with water	328	83.00

Table 2. Characteristics of respondents' and chicken production facilities on the farm.

Variable		**Frequency**	**Percentage**
Has the farmer attended a specific course on broiler chicken husbandry	No	365	92.40
	Yes	30	7.60
Has the chicken production facility been authorized by local authorities?	No	338	85.60
	Yes	57	14.40
Has the chicken producer been registered with a chicken producers Commission?	No	354	89.60
	Yes	41	10.40
Is chicken production your main source of income?	No	106	26.80
	Yes	289	73.20
Farming systems	Intensive	395	100.00
	Semi-intensive	0	0.00
	Extensive	0	0.00
Number chickens	50 to 500	325	82.30
	501 to 999	50	12.70
	More than 1000	20	5.00
What is the mortality rate?	Less than 20	318	80.50
	21 to 50	51	12.90
	51 to 100	20	5.10
	More than 100	6	1.50
Has the chicken production activity been inspected by a livestock service inspector	No	366	92.70
	Yes	29	7.30
How often do you receive the inspection?	Semiannually	24	82.80
	Monthly	3	10.30
	Annually	2	6.90
Have you ever received any penalty/warning for non-compliance	No	21	72.40
	Yes	8	27.60

importance of maintaining a clean working environment to prevent contamination (99.7%) with no significant district differences ($\chi2 = 2.565$, $P = 0.633$). However, awareness regarding the routine cleaning of chicken litter to mitigate cross-contamination exhibits significant district variation ($\chi2 = 10.929$, $P = 0.027$), indicating inconsistencies in adherence to practices, especially in KaMubukwana (94.3%). Washing drinkers and feeders with warm water

Table 3. Smallholder chicken farmers' biosecurity knowledge.

Personal hygiene knowledge	Total (%)	Name of district (%)					Chi-square test	
		KaMavota	KaMubukwana	KaNlhamakulu	Xai-Xa	Massinga	χ2	P-value
A	387 (98)	110 (99.1)	102 (97.1)	87 (100)	46 (93.9)	42 (97.7)	7.037	0.134
B	358 (90.6)	87 (78.4)	103 (98.1)	87 (100)	48 (98)	33 (76.7)	48.382	<0.001
C	369 (93.4)	107 (96.4)	103 (98.1)	78 (89.7)	40 (81.6)	41 (95.3)	18.669	0.001
D	191 (48.4)	83 (74.8)	45 (42.9)	24 (27.6)	9 (18.4)	30 (69.8)	72.862	<0.001
E	162 (41)	57 (51.4)	38 (36.2)	17 (19.5)	36 (73.5)	14 (32.6)	45.102	<0.001
F	320 (81)	59 (53.2)	99 (94.3)	87 (100)	48 (98)	27 (62.8)	106.86	<0.001
G	371 (93.9)	92 (82.9)	105 (100)	87 (100)	49 (100)	38 (88.4)	41.625	<0.001

A) Washing your hands regularly with detergent/soap and warm water reduces the risk of contamination, B) Do you wash your hands after using the bathroom and touching your hair or nose, C) Wearing apron, mask, gloves, boots and caps can prevent food contamination, D) Caring for chickens with bare hands is harmful to their and your health, E) Producer should avoid working when it has flu, colds, cough and diarrhea, even when washing hands regularly, F) Proper cleaning, disinfection and handling of instruments can reduce cross contamination, G) Work equipment and tools can be sanitized by boiling/steaming, chlorine bath and ultraviolet light to reduce contamination, P= Significance.

Table 4. Biosecurity knowledge regarding cross-contamination.

Hygiene knowledge	Total (%)	Name of district (%)					Chi-square test	
		KaMavota	KaMubukwana	KaNlhamakulu	Xai-Xai	Massinga	χ2	P-value
A	394 (99.7)	110 (99.1)	105 (100)	87 (100)	49 (100)	43 (100)	2.56505	0.633
B	391 (99)	110 (99.1)	105 (100)	85 (97.7)	48 (98)	43 (100)	3.48042	0.481
C	387 (98)	109 (98.2)	99 (94.3)	87 (100)	49 (100)	43 (100)	10.9292	0.027
D	383 (97)	101 (91)	105 (100)	87 (100)	49 (100)	41 (95.3)	21.3658	<0.001
E	391 (99)	108 (97.3)	105 (100)	86 (98.9)	49 (100)	43 (100)	5.19442	0.268
F	248 (62.8)	74 (66.7)	68 (64.8)	30 (34.5)	34 (69.4)	42 (97.7)	54.0328	<0.001
G	222 (56.2)	56 (50.5)	58 (55.2)	18 (20.7)	47 (95.9)	43 (100)	111.014	<0.001
H	359 (90.9)	99 (89.2)	86 (81.9)	83 (95.4)	48 (98)	43 (100%)	20.0246	<0.001
I	89 (22.5)	20 (18.0)	32 (30.5)	9 (10.3)	4 (8.2)	24 (55.8)	45.579	0.000

A) A footbath and clean working environment is essential in the prevention of contamination ,B) Separating dirty zone from clean zone can reduce cross contamination, C) Regularly cleaning chicken litter reduces cross-contamination, D) Wash drinkers and feeders before feeding chickens with warm water and disinfectant, E) Cleaning, washing and disinfecting contact surfaces before and after introducing chickens, F) Separating sick chickens from healthy ones reduces cross-contamination, G) Do you burn or bury the dead chickens, H) Do you protect the farm from other animals, I) Have you ever heard of *Salmonella*, *Campylobacter*, *E. coli* and *S. aureus*, P= Significance.

and disinfectant before feeding chickens is widely recognized (97%) but varied significantly among districts ($\chi2 = 21.366$, $P < 0.001$), indicating potential compliance issues, especially in KaMavota (91%). Knowledge regarding separating sick from healthy chickens was lower (62.8%) and varied significantly ($\chi 2$ = 54.033, P < 0.001), with KaNlhamakulu showing low compliance (34.5%). Practices such as disposing of dead chickens through burning or burying and protecting the farm from other animals showed significant difference, especially in KaNlhamakulu (20.7% for item G) ($\chi 2$ = 111.014, P < 0.001) and KaMubukwana (81.9% for item H) ($\chi 2$ = 20.025, P < 0.001).

Table 5 illustrates the impact of demographic factors on the biosecurity knowledge of smallholder farmers, using both chi-square (P^{+}-value) and regression (P-Value) tests. Males' demonstrated better knowledge (71.5%) compared to females (63.3%). Age shown a moderate effect on knowledge scores (P=0.022), indicating that it influenced food safety knowledge. Education level, residence area, and training credentials shown significant associations where, high school graduates had a much higher percentage of good knowledge (85.5%) compared to those with only secondary education (60.9%). Urban dwellers exhibited superior knowledge scores of 92.4%, in contrast to peri-urban respondents who scored 58.7%, with both (P^{+}< 0.001) and (P< 0.001) indicating significant outcomes. A similar trend is observed in training attendance, with individuals who had food safety training (84.7%) achieving markedly higher scores than those who did not (59.2%).

Evaluation of smallholder chicken farmers' biosecurity attitude

Chicken producers strongly agreed that good personal hygiene and other practices are essential to prevent foodborne diseases and contamination within chicken production, as displayed in Table 6. In terms of awareness about foodborne diseases being harmful to people, willingness to change incorrect chicken farming behaviors, and careful disposal of production waste, no significant differences were found (χ^2 = 7.748, P = 0.257; χ^2 = 9.762, P = 0.135; χ^2 = 7.934, P = 0.243, respectively), indicating a positive attitude toward improving chicken production. A majority (99.7%) of respondents strongly agreed that training in biosecurity is important, and contaminated water was widely recognized as a cause of disease in chickens (99.3%), but responses varied significantly (χ^2 = 27.687, P < 0.001; χ^2 = 24.890, P < 0.001) between farmers with only primary education and those with higher education, with the latter more strongly agreeing on the importance of biosecurity training and avoiding the use of contaminated water.

The attitude toward safe chicken production was high (100%), and there was a strong consensus on the importance of foot bath use and decontaminating chicken farms (98.4%), but statistically significant differences were observed (χ^2 = 16.435, P = 0.001; χ^2 = 24.890, P = 0.001), with producers having secondary and higher education levels being more aware. There were also notable differences between participants in some areas, such as using protective clothing, separating sick chickens to reduce contamination, protecting feed from contaminants, and practicing good personal hygiene to prevent foodborne diseases. Farmers with higher levels of education also showed better attitudes in these areas. This suggests that formal education and experience based on practical knowledge can lead to strong beliefs about positive biosecurity attitudes. Enhancing current attitudes and ensuring the continuous application of best practices should be the main goals of farmer training.

Table 7 illustrates the impact of demographic characteristics on food safety in relation to farmers' bio-security attitude. Males demonstrated slightly better attitudes (83.5%) compared to females (78.9%). There was no significant association between age and attitudes (P=0.279), however the respondents under the age of 20 had the highest percentage of positive attitude (90.9%). Education level and training credentials are strongly associated with food safety regarding bio-security attitudes. High school graduates exhibited the highest percentage of good attitudes (93.5%) with a mean score of 87.19 ± 10.28. The results show that attitudes are considerably affected by education level, with higher education resulting in better attitudes (P^{+}<0.001, P<0.001). Likewise, attitudes were noticeably improved among participants in the food safety training (95.5%, mean score of 89.71 ± 10.1) when contrasted with those of non-trainees (74.8%, mean score of 79.91 ± 9.68).

Assessment of food safety and biosecurity practices of smallholder chicken farmers

Table 8 demonstrates the evaluation of the bio-security practices of chicken producers based on their education levels. The findings indicate statistically significant differences for several practices. The habit of washing hands with soap before and after feeding chickens varied significantly across education levels ($\chi 2$ = 15.061, df = 6, P = 0.02), with those having high school education reporting the highest compliance (80.6%). Similarly, washing hands with soap after using the toilet also showed significant differences ($\chi 2$ = 20.138, df = 6, P = 0.003), with those without formal education less likely to comply (34%). Wearing protective clothing during chicken husbandry was significantly associated with education level ($\chi 2$ = 15.345, df = 6, P = 0.018), with higher education linked to better compliance. Practices such as cleaning and disinfecting poultry houses and washing and sanitizing utensils did not show significant associations with education, suggesting consistent practices across all education level.

Table 9 indicates the effect of demographic factors on biosecurity practices of smallholder chicken farmers. The chi-square and regression analyses (P^{+} = 0.262, P =

Table 5. Effect of gender, age, education level, residence area, training credentials on the biosecurity knowledge of smallholder farmers.

Characteristic	Number of respondents (%)			P⁺-value	Mean ± SD	Range	P-value
	Poor (<50) n (%)	Medium (≥50 to <75) n (%)	Good (≥75) n (%)				
Gender							
Female	0 (0%)	87 (36.7%)	150 (63.3%)	0.089	83.23 ± 10.73	53.33-100	0.289
Male	0 (0%)	45 (28.5%)	113 (71.5%)		83.29 ± 10.5	53.33-100	
Age of respondent							
Less than 20 years	0 (0%)	6 (27.3%)	16 (72.7%)	0.228	82.12 ± 9.95	66.67-100	0.022
20-40 years	0 (0%)	35 (27.1%)	94 (72.9%)		84.03 ± 10.42	53.33-100	
41-60 years	0 (0%)	78 (37.1%)	132 (62.9%)		82.7 ± 10.62	53.33-100	
Above 60 years	0 (0%)	13 (38.2%)	21(61.8%)		84.51 ± 11.92	66.67-100	
Marital status							
Married	0 (0%)	65 (35.1%)	120 (64.9%)	0.138	83.42 ± 10.61	60-100	0.305
Unmarried, living with a partner	0 (0%)	47 (38.2%)	76 (61.8%)		81.3 ±10.37	53.33-100	
Unmarried, living without a partner	0 (0%)	16 (27.6%)	42 (72.4%)		84.48 ± 10.37	53.33-100	
Separated	0 (0%)	1 (6.7%)	14 (93.3%)		88.89 ± 6.98	73.33-100	
Divorced	0 (0%)	0 (0%)	1 (100%)		100	100-100	
Widowed	0 (0%)	3 (23.1%)	10 (76.9%)		86.15 ± 9.99	66.67-100	
Education level							
High school level (Over 12)	0 (0%)	9 (14.5%)	53 (85.5%)	0.001	88.06 ± 9.44	66.67-100	<0.001
Secondary school level (grade 7-12)	0 (0%)	93 (39.1%)	145 (60.9%)		81.93 ± 10.55	60-100	
Primary school level (grade 1-6)	0 (0%)	20 (37.7%)	33 (62.3%)		82.52 ± 11.19	53.33-100	
No formal education	0 (0%)	10 (23.8%)	32 (76.2%)		84.6 ± 10.15	60-100	
Residence area							
Rural	0 (0%)	0 (0%)	0 (0%)	<0.001			<0.001
Peri-urban	0 (0%)	125 (41.3%)	178 (58.7%)		81.89 ± 11.14	53.33-100	
Urban	0 (0%)	7 (7.6%)	85 (92.4%)		87.75 ± 7.08	66.67-100	
Have you ever attended a training course on biosecurity							
No	0(0%)	115(40.8%)	167(59.2%)	<0.001	80.69 ± 9.74	53.33-100	<0.001
Yes	0(0%)	17(15.3%)	94(84.7%)		89.79 ± 10.08	60-100	

n= Number of processors SD = Standard deviation, p⁺-value = test for association by Chi-square test, p-value = test for effect by one way ANOVA, P= Significance.

Table 6. Food safety based on the biosecurity attitude of smallholder farmers.

Variable		Total (%)	Education level (%)				Chi-square test	
			High school level (Over 12)	Secondary school level (grade 7-12)	Primary school level (grade 1-6)	No formal education	χ2	P-value
	Strongly agree	242 (61.3)	42 (67.7)	143 (60.1)	26 (49.1)	31 (73.8)		
A	Agree	150 (38)	20 (32.3)	95 (39.9)	25 (47.2)	10 (23.8)	17.088	0.009
	Disagree	3 (0.8)	0 (0)	0 (0)	2 (3.8)	1 (2.4)		
	Strongly agree	128 (32.4)	28 (45.2)	74 (31.1)	12 (22.6)	14 (33.3)	7.748	0.257
B	Agree	266 (67.3)	34 (54.8)	163 (68.5)	41 (77.4)	28 (66.7)		
	Disagree	1 (0.3)	0 (0)	1 (0.4)	0 (0)	0 (0)		
	Strongly agree	193 (49.1)	45 (72.6)	98 (41.5)	21 (39.6)	29 (69)	27.687	<0.001
C	Agree	200 (50.9)	17 (27.4)	138 (58.5)	32 (60.4)	13 (31)		
	Disagree	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)		
	Strongly agree	165 (41.8)	37 (59.7)	102 (42.9)	14 (26.4)	12 (28.6)	16.435	0.001
D	Agree	230 (58.2)	25 (40.3)	136 (57.1)	39 (73.6)	30 (71.4)		
	Disagree	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	21.146	0.002
	Strongly agree	186 (47.1)	39 (62.9)	106 (44.5)	15 (28.3)	26 (61.9)		
E	Agree	206 (52.2)	23 (37.1)	131 (55)	37 (69.8)	15 (35.7)		
	Disagree	3 (0.8)	0 (0)	1 (0.4)	1 (1.9)	1 (2.4)	15.985	0.014
	Strongly agree	257 (65.1)	48 (77.4)	158 (66.4)	29 (54.7)	22 (52.4)		
F	Agree	137 (34.7)	13 (21)	80 (33.6)	24 (45.3)	20 (47.6)		
	Disagree	1 (0.3)	1 (1.6)	0 (0)	0 (0)	0 (0)		
	Strongly agree	306 (77.5)	53 (85.5)	195 (81.9)	35 (66)	23 (54.8)	24.890	<0.001
G	Agree	86 (21.8)	8 (12.9)	41 (17.2)	18 (34)	19 (45.2)		
	Disagree	3 (0.8)	1 (1.6)	2 (0.8)	0 (0)	0 (0)		
	Strongly agree	271 (68.6)	50 (80.6)	155 (65.1)	29 (54.7)	37 (88.1)	20.288	0.002
H	Agree	109 (27.6)	9 (14.5)	75 (31.5)	20 (37.7)	5 (11.9)		
	Disagree	15 (3.8)	3 (4.8)	8 (3.4)	4 (7.5)	0 (0)		
	Strongly agree	219 (55.4)	46 (74.2)	130 (54.6)	20 (37.7)	23 (54.8)	23.758	0.001
I	Agree	170 (43)	13 (21)	106 (44.5)	32 (60.4)	19 (45.2)		
	Disagree	6 (1.5)	3 (4.8)	2 (0.8)	1(1.9)	0 (0)		
	Strongly agree	182 (46.1)	36 (58.1)	111 (46.6)	16 (30.2)	19 (45.2)	13.193	0.040
J	Agree	113 (28.6)	16 (25.8)	68 (28.6)	15 (28.3)	14 (33.3)		
	Disagree	100 (25.3)	10 (16.1)	59 (24.8)	22 (41.5)	9 (21.4)		

Table 6. Contd.

K	Strongly agree	158 (40)	30 (48.4)	98 (41.2)	16 (30.2)	14 (33.3)	9.762	0.135
	Agree	203 (51.4)	26 (41.9)	125 (52.5)	31 (58.5)	21 (50)		
	Disagree	34 (8.6)	6 (9.7)	15 (6.3)	6 (11.3)	7 (16.7)		
L	Strongly agree	138 (34.9)	28 (45.2)	80 (33.6)	14 (26.4)	16 (38.1)	7.934	0.243
	Agree	254 (64.3)	34 (54.8)	157 (66)	38 (71.7)	25 (59.5)		
	Disagree	3 (0.8)	0 (0)	1(0.4)	1 (1.9)	1 (2.4)		

A) Good personal hygiene can avoid foodborne illnesses, B) Foodborne diseases are more harmful to vulnerable people, C) Training in biosecurity is important, D) Safe production of chicken and personal hygiene is important, E) Use of appropriate protective clothing reduces contamination, F) Washing drinking fountains and feeders with treated water (chlorine) regularly can prevent chicken contamination, G) Contaminated water can cause illness in chickens, H) Important to store water, protect feed from contaminants, I) Footbath, decontaminating and disinfecting the chicken farm reduces contamination, J) Separating sick chickens reduces contamination, K) Willing to change wrong chicken farming behaviors, L) Necessary to dispose of production waste carefully, p = Significance value.

0.667) reveal that gender is not a significant factor influencing biosecurity practices. The average scores for females (83.88 ± 7.36) and males (84.28 ± 8.16) were nearly equivalent. However, the age of respondents showed a significant $P^{+} = 0.006$, suggesting variability in biosecurity practices among different age groups. The regression analysis (P = 0.021) indicated that marital status influences biosecurity practices, with married respondents exhibiting a slightly higher mean score (85.34 ± 7.95) than other groups, suggesting that married individuals may have better practices. The $P^{+} = 0.12$ for education level suggests no significant difference between groups; however, the regression analysis (P = 0.009) reveals a significant effect, with respondents having a high school education level scoring higher (86.83 ± 6.32). The residence area also showed a significant relationship (P < 0.001), indicating that living in urban areas is positively associated with better biosecurity practices, with urban respondents having a higher mean score (85.64 ± 5.74). Training credentials had a significant effect on practices (P < 0.001). Participants who had attended training scored significantly higher (87.91 ± 7.52) compared to those who did not receive training (82.52 ± 7.24). This indicates that training is crucial for enhancing food safety regarding biosecurity practices.

Table 10 presents the correlation coefficients among demographic variables, highlighting their strength and significance. Significant correlations include a positive relationship between Residence Area (RA) and Biosecurity Knowledge (BK) (r = 0.233, p < 0.01) and Biosecurity Practice (BP) (r = 0.115, p < 0.05). This implies that living in a peri-urban area is associated with good biosecurity knowledge and positive practices. Age and Residence Area (RA) (r = -0.265, p < 0.01) and Age and Marital Status (MS) were negatively correlated (r = -0.173, p < 0.01). This suggests that younger farmers are more likely to reside in peri-urban areas and are single, whereas older farmers live in urban areas and are married. A significant positive correlation was observed between Education Level (EL) and Residence Area (RA) (r = 0.258, p < 0.01), and a negative correlation was observed between EL and Biosecurity Attitude (BA) (r = -0.258, p < 0.01). Training is strongly correlated with BK (r = 0.385, p < 0.01), BA (r = 0.412, p < 0.01), and BP (r = 0.316, p < 0.01).

These results show that training is essential for enhancing biosecurity knowledge, attitudes, and practices. The relationships between RA and biosecurity knowledge and practices demonstrate that residential area influences biosecurity knowledge and practices. To maximize biosecurity practice, future interventions should prioritize training initiatives and consider the residential setting.

DISCUSSION

The lack of adherence to bio-security measures in the intensive production of broilers chicken promotes the spread of pathogenic microbes (Adesola et al., 2025; Kabeta et al., 2024). Due to the tropical climate and the prevalence of intensive production, chicken producers in Mozambique often experience respiratory diseases and diarrhea (FAO, 2013). Respiratory disease and diarrhea are more common infections on chicken farms (Sawadogo et al., 2023). These results are in with that found in Togo, respiratory diseases and

Table 7. Effect of gender, age, education level, residence area, training credentials on the food safety regarding biosecurity attitude of smallholder chicken farmers.

Characteristic	Number of respondents (%)			P⁺-value	Mean ± SD	Range	P-value
	Poor	Medium	Good				
Gender							
Female	0 (0)	50 (21.1)	187 (78.9)	0.252	83.03 ± 11.23	58.33-100	0.193
Male	0 (0)	26 (16.5)	132 (83.5)		82.07 ± 9.92	58.33-100	
Age of respondent							
Less than 20 years	0 (0)	2 (9.1)	20 (90.9)	0.286	80.43 ± 6.33	63.89-91.67	0.279
20-40 years	0 (0)	25 (19.4)	104 (80.6)		82.41 ± 10.72	61.11-100	
41-60 years	0 (0)	39 (18.6)	171 (81.4)		83.2 ± 10.75	58.33-100	
Above 60 years	0 (0)	10 (29.4)	24 (70.6)		81.54 ± 12.77	58.33-100	
Marital status							
Married	0 (0)	34 (18.4)	151 (81.6)	0.679	83.75 ± 11.16	58.33-100	0.153
Unmarried, living with a partner	0 (0)	25 (20.3)	98 (79.7)		82.05 ± 10.63	61.11-100	
Unmarried, living without a partner	0 (0)	12 (20.7)	46 (79.3)		80.56 ± 9.48	61.11-100	
Separated	0 (0)	1 (6.7)	14 (93.3)		82.96 ± 8.39	66.67-100	
Divorced	0 (0)	0 (0)	1 (100)		100	100-100	
Widowed	0 (0)	4 (30.8)	9 (69.2)		80.13 ± 11.5	61.11-100	
Education level							
High school level (Over 12)	0 (0)	4 (6.5)	58 (93.5)	<0.001	87.19 ± 10.28	61.11-100	<0.001
Secondary school level (grade 7-12)	0 (0)	50 (21)	188 (79)		82.5 ± 10.71	61.11-100	
Primary school level (grade 1-6)	0 (0)	20 (37.7)	33 (62.3)		77.67 ± 11.61	58.33-100	
No formal education	0 (0)	2 (4.8)	40 (95.2)		83 ± 7.05	72.22-100	
Residence area							
Rural	0 (0)	0 (0)	0 (0)	<0.001			0.072
Peri-urban	0 (0)	74 (24.4)	229 (75.6)		82.77 ± 11.91	58.33-100	
Urban	0 (0)	2 (2.2)	90 (97.8)		82.22 ± 5.19	72.22-100	
Have you ever attended a training course on food safety and antibiotic use							
No	0 (0)	71 (25.2)	211 (74.8)	<0.001	79.91 ± 9.68	58.33-100	<0.001
Yes	0 (0)	5 (4.5)	106 (95.5)		89.71 ± 10.1	61.11-100	

n= Number of processors SD = Standard deviation, p⁺-value = test for association by Chi-square test, p-value = test for effect by one way ANOVA, p = Significance value.

diarrhea predominantly occur during chicken production (Bedekelabou et al., 2022). Disease poses a significant challenge in chicken production, quickly spreading among animals, reducing productivity, and leading to mortality, which affects the income of smallholder farmers (Khalil et al., 2023; MacPhillamy et al., 2022; Pao et al., 2023). Additionally, these results are similar to those found in Tanzania where farmers confirmed that respiratory diseases, typhoid and diarrhea frequently occur, precarious housing was also observed, with unhygienic conditions and limited air circulation in the poultry farmers (Kimera et al., 2020).

The study demonstrated that 81.3% of respondents own the production, 80.5% had land ownership, 82.0% use electricity and charcoal in farms. This was similar to those observed by Siddiky et al. (2022) who reported that 86.48% smallholders owned the production themselves. The findings in Nigeria indicate that land ownership significantly influences the adoption of bio-security measures among smallholders. Those who own land were more inclined to invest in technologies and infrastructures that enhance the well-being of chickens (Olutumise et al., 2023).

The findings indicated that only 28.2% of smallholders received informal training in food safety related to bio-security. Additionally, 73.2% identified broiler chicken production as their primary income source, 83.3% of the respondents reported introducing batches ranging from

Table 8. Assessment of Food safety and biosecurity practices of smallholder chicken farmers.

Variable		Total	Education level				Test statistics		
			High school level	Secondary school level	Primary school level	No formal education	χ2	df	P-value
	Always	244 (61.8)	50 (80.6)	134 (56.3%)	30 (56.6)	30 (71.4)			
A	Sometimes	150 (38)	12 (19.4)	103 (43.3)	23 (43.4)	12 (28.6)	15.061	6	0.02
	Never	1 (0.3)	0 (0)	1 (0.4)	0 (0)	0 (0)			
	Always	243 (61.5)	47 (75.8)	138 (58)	30 (56.6)	28 (66.7)			
B	Sometimes	145 (36.7)	15 (24.2)	95 (39.9)	23 (43.4)	12 (28.6)	11.947	6	0.063
	Never	7 (1.8)	0 (0)	5 (2.1)	0 (0)	2 (4.8)			
	Always	251 (63.5)	43 (69.4)	141 (59.2)	38 (71.7)	29 (69)			
C	Sometimes	130 (32.9)	16 (25.8)	88 (37)	14 (26.4)	12 (28.6)	5.744	6	0.452
	Never	14 (3.5)	3 (4.8)	9 (3.8)	1 (1.9)	1 (2.4)			
	Always	314 (79.5)	46 (74.2)	193 (81.1)	42 (79.2)	33 (78.6)			
D	Sometimes	74 (18.7)	14 (22.6)	41 (17.2)	11 (20.8)	8 (19)	2.974	6	0.812
	Never	7 (1.8)	2 (3.2)	4 (1.7)	0 (0)	1 (2.4)			
	Always	215 (54.4)	41 (66.1)	129 (54.2)	18 (34)	27 (64.3)			
E	Sometimes	178 (45.1)	21 (33.9)	109 (45.8)	34 (64.2)	14 (33.3)	20.138	6	0.003
	Never	2 (0.5)	0 (0)	0 (0)	1 (1.9)	1 (2.4)			
	Always	94 (23.8)	24 (38.7)	53 (22.3)	6 (11.3)	11 (26.2)			
F	Sometimes	288 (72.9)	37 (59.7)	178 (74.8)	43 (81.1)	30 (71.4)	15.345	6	0.018
	Never	13 (3.3)	1 (1.6)	7 (2.9)	4 (7.5)	1 (2.4)			
	Always	66 (16.7)	14 (22.6)	41 (17.2)	4 (7.5)	7 (16.7)			
G	Sometimes	323 (81.8)	46 (74.2)	195 (81.9)	48 (90.6)	34 (81)	7.084	6	0.313
	Never	6 (1.5)	2 (3.2)	2 (0.8)	1 (1.9)	1 (2.4)			
	Always	271 (68.6)	43 (69.4)	165 (69.3)	39 (73.6)	24 (57.1)			
H	Sometimes	123 (31.1)	19 (30.6)	73 (30.7)	14 (26.4)	17 (40.5)	11.001	6	0.088
	Never	1 (0.3)	0 (0)	0 (0)	0 (0)	1 (2.4)			

A) Do you wash your hands with soap before and after feeding chickens, B) Do you have soap/detergents in the toilet, C) Do you feed the chickens while sick (diarrhea, cough, cold or flu), D) Do you clean and disinfect all areas of the poultry house before and after production, E) Do you wash your hands with soap after going to the toilet, F) Do you wear protective clothing during chicken husbandry, G) Do you wash and sanitize your work clothes, H) Do you wash and sanitize utensils before and after feeding the chicken, p = Significance value.

Table 9. Effect of gender, age, education level, residence area, training credentials on the food safety regarding biosecurity practices of smallholder's chicken farmers.

Characteristic	Number of respondents (%)			P^+-value	Mean ± SD	Range	P-value
	Poor	Medium	Good				
Gender							
Female	0 (0)	14 (5.9)	223 (94.1)	0.262	83.88 ± 7.36	62.5-100	0.667
Male	0 (0)	14 (8.9)	144 (91.1)		84.28 ± 8.16	58.33-100	
Age of respondent							
Less than 20 years	0 (0)	0 (0)	22 (100)	0.006	86.36 ± 6.7	75-95.83	0.833
20-40 years	0 (0)	17 (13.2)	112 (86.8)		84.04 ± 7.64	62.5-100	
41-60 years	0 (0)	8 (3.8)	202 (96.2)		83.91 ± 7.45	66.67-100	
Above 60 years	0 (0)	3 (8.8)	31 (91.2)		83.33 ± 9.68	58.33-100	
Marital status							
Married	0 (0)	7 (3.8)	178 (96.2)	0.13	85.34 ± 7.95	58.33-100	0.021
Unmarried, living with a partner	0 (0)	14 (11.4)	109 (88.6)		82.45 ± 7.64	62.5-100	
Unmarried, living without a partner	0 (0)	6 (10.3)	52 (89.7)		83.05 ± 6.97	70.83-100	
Separated	0 (0)	1 (6.7)	14 (93.3)		85.28 ± 6.07	70.83-91.67	
Divorced	0 (0)	0 (0)	1 (100)		83.33	83.33-83.33	
Widowed	0 (0)	0 (0)	13 (100)		83.65 ± 6.47	75-100	
Education level							
High school level (Over 12)	0 (0%)	1 (1.6%)	61 (98.4%)	0.12	86.83 ± 6.32	70.83-100	0.009
Secondary school level (grade 7-12)	0 (0)	17 (7.1)	221 (92.9)		83.58 ± 7.88	62.5-100	
Primary school level (grade 1-6)	0 (0)	7 (13.2)	46 (86.8)		82.39 ± 7.87	58.33-100	
No formal education	0 (0)	3 (7.1)	39 (92.9)		84.62 ± 7.33	70.83-100	
Residence area							
Rural	0 (0)	0 (0)	0 (0)	0.242			<0.001
Peri-urban	0 (0)	24 (7.9)	279 (92.1)		83.55 ± 8.13	58.33-100	
Urban	0 (0)	4 (4.3)	88 (95.7)		85.64 ± 5.74	66.67-100	
Have you ever attended a training course on food safety regarding biosecurity							
No	0 (0)	24 (8.5)	258 (91.5)	0.089	82.52 ± 7.24	58.33-100	<0.001
Yes	0 (0)	4 (3.6)	107 (96.4)		87.91 ± 7.52	62.5-100	

n= Number of processors SD = Standard deviation, p^+-value = test for association by Chi-square test, p-value = test for effect by one way ANOVA, p = Significance value.

Table 10. Correlation matrix of demographic factors and food safety regarding bio security variables.

Variable	Gender	Age	MS	EL	RA	Training	BK	BA	BP
Gender	1								
Age	-0.176**	1							
MS	-0.01	-0.173**	1						
EL	0.125*	0.075	0.083	1					
RA	0.174**	-.265**	0.271**	0.258**	1				
Training	0.077	-0.026	-0.043	0.019	-0.067	1			
BK	0.003	-0.002	0.086	-0.065	0.233**	0.385**	1		
BA	-0.044	0.03	-0.082	-0.148**	-0.022	0.412**	0.429**	1	
BP	0.026	-0.058	-0.082	-0.085	0.115*	0.316**	0.418**	0.507**	1

MS is marital status, EL is educational level, RA is residence area, BK is biosecurity knowledge, BA is biosecurity attitude, BP is biosecurity practice, ** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed).

100 to 500 in an intensive system. The results support the findings of (Chilawa et al. 2022) indicating that the majority of farmers produce between 101 and 300 chickens per batch. Bissong et al. (2022) reported that the majority of producers were farm owners, untrained, with a production capacity of 500 chicken per cycle. In contrast to the current findings, Sawadogo et al. (2023) reported that most farms maintain over 500 chickens; however, their results align with the observation that the majority utilize a total confinement system for chicken production. The research conducted by Hossain et al. (2022) and Sawadogo et al. (2023) indicates that a limited number of smallholders received training in poultry production. The production of broiler chickens serves as an alternative to unemployment in numerous underdeveloped countries. Hassan et al. (2021) and Hassan et al. (2021); Siddiky et al. (2022) found that most smallholders rely on this activity as their primary source of income rather than agriculture or fishing.

Smallholder chicken farmers exhibited substantial knowledge of hand washing post-toilet use (90.6%) and the utilization of personal protective clothing (93.4%); however, their awareness concerning the health risks of handling chickens with bare hands was inadequate (48.4%), as was their understanding of the necessity to refrain from working while sick (41.0%). The results can be attributed to the support provided to farmers following the acquisition of chicks, as many suppliers offer guidance to optimize production and enhance profitability. Producers predominantly utilize masks and scarves for head coverings, especially among women. Moreover, the absence of gloves and other protective equipment may facilitate the transmission of pathogenic bacteria, notably *E. coli* and *S. aureus*, with humans serving as the primary reservoir for the latter. Farmers may become contaminated if bio-security protocols are not adhered to during production.

A similar study indicated that farmers did not utilize protective equipment, such as masks and gloves (Bissong et al., 2022). Ahmed et al. (2024) found that respondents engaged in negative practices, including the failure to wear gloves, masks, and boots while working on farms. A study conducted in Togo reported similar results in which smallholders had better knowledge regarding bio-security, combined with high levels of education. Furthermore, the majority of chicken farmers received training to manage farms, necessitated by the sensitivity of the activity, which demands a fundamental understanding to ensure income and profitability (Bedekelabou et al., 2022). Comparable results have been observed in Nigeria, where farmers with training and land ownership exhibited enhanced knowledge regarding bio-security practices (Olutumise et al., 2023). Tufa et al. (2023) indicate that farmers engaged in broiler production exhibit enhanced knowledge due to their pursuit of supplementary training in bio-security management. Contrary to the findings of the present study, Abd-Elwahed Ibrahim Mahmoud et al. (2023) observed that a nearly half of the producers (56.2%) exhibited poor knowledge regarding health management practices on chicken farms. This result is due to the lack of biosecurity training programs on chicken production.

The current study showed that 99% of smallholders' chicken farmers had good knowledge on cleaning the environment, disinfecting contact surfaces, separating the dirty area from the clean area but most farmers don't use footpaths. Farmers reported that after each production cycle, they remove the litter and disinfect the surfaces, roof, windows and curtains. Previous study reported that farmers who used good bio-security based on footpaths, efficient cleaning, disinfection on farms reported low occurrence of diseases (Bedekelabou et al., 2022). Another similar study conducted in Bangladesh found that 91.89% of respondents sprayed disinfectant at regular intervals to clean farm premises and most of them 95.95% had no foot baths (Siddiky et al., 2022). Bedekelabou et al. (2022) assert that footbaths can inhibit the incursion of germs, and that infectious diseases can be managed by fundamental biosecurity protocols. Pym (2013) states that most smallholders in Africa lack footbaths, permitting resellers to traverse multiple farms to purchase chickens without implementing biosecurity protocols, hence facilitating the transmission of diseases among farms.

Inadequate knowledge was confirmed, with statistically significant differences seen in the studied districts for the regular cleaning of litter in the KaMubukwana District (P=0.027), whereas, in the KaMavota District, the cleaning of drinkers and feeders exhibited statistically significant differences (P<0.001). In KaNlhamakulu District (P< 0.001), inadequate information was confirmed regarding the segregation of sick chickens from healthy ones, as well as concerning the biosecurity measures for deceased chickens, namely through incineration or burying. In the districts studied, some farmers clean the bedding (sawdust, rice husks or sand), removing the wet part, others air the litter by pricking it with a stick for better air circulation, because of high cost of sawdust producers prefer to remove the litter at the end of the production cycle and manure is used on farms, in the garden, offer, sell or throw it in garbage containers. Bissong et al. (2022) noted that smallholders sell or consume the dead chickens but others bury them, and eating chicken carcasses can spread diseases from farms to nearby communities. Additionally, Kabeta et al. (2024) identified that farmers had poor knowledge regarding effects of salmonellosis on chickens, risk posed by chicken manure in contaminating farms with *Salmonella* and the significance of appropriate bio-security practices in preventing its infections.

Contrary results were observed in Bangladesh, where smallholders forgo bedding, opting instead for ash or sand as litter due to cost-effectiveness; the use of ash is also associated with the assumption that it can mitigate parasites and odors on farms (Khalil et al., 2023). According to Sawadogo et al. (2023), 90% of farmers utilized manure as fertilizer for agricultural crops, while some left waste on their fields. Pym (2013) and Siddiky et al. (2022) assert that maintaining a clean shed by eliminating residual feed in feeders, disinfecting the premises, and administering vaccinations enhances health, mitigates parasites, minimizes microbiological contamination, and decreases the presence of vermin and flies. In addition, litter and manure can contain pathogenic microorganisms that can affect the health of workers which makes the implementation of hygiene, use of masks, gloves, eye shields and other protective equipment is crucial (Ajayi et al., 2025; Khalil et al., 2023; Kullan et al., 2024). Dumping untreated manure can transmit pathogens and antibiotic residues into the environment or onto food crops that are consumed by humans or animals when it is disposed outdoors or used as fertilizer (Checcucci et al., 2020). On the farm, Olutumise et al. (2023) recommend cleaning the litter, as direct contact between the litter and the chicken might cause diseases to spread through feces, harming the poultry's health and growth. Singh et al. (2018) and Zhang et al. (2023) recommend burial, rendering, incineration, composting, using as livestock feed, fertilizer, or energy source, but emphasize the importance of using Good Hygiene Practices (GHP) to avoid contamination.

In the farms surveyed, drinkers are cleaned daily but not consistently, while feeders are rinsed at the end of each production cycle. Most smallholders do not isolate sick birds from healthy ones, a practice that may foster conditions conducive to cross-contamination in production. The findings indicate that in order to guarantee bio-security in production and enhance management conditions, smallholders require training. The research conducted by (Khalil et al., 2023) emphasizes the significance of educating and teaching smallholders on bio-security practices and the transmission of diseases. A study demonstrated that farmers participating in training on disease control and bio-security exhibited significant knowledge (Tufa et al., 2023). Similar results were observed in Cameroon and Bangladesh, indicating that producers with higher educational levels demonstrated good knowledge compared to their peers (Ahmed et al., 2024; Bissong et al., 2022). A significant correlation exists between educational attainment and knowledge of bio-security measures concerning waste management, disposal of deceased chickens, and vaccination practices ($P<0.05$).

The authors highlighted the importance of educating farmers on effective bio-security practices concerning vaccination and hygiene protocols (Siddiky et al., 2022).

The current study indicates that a significant majority of smallholders (98.5%) believe that GHP can mitigate disease occurrence. However, 77.5% of respondents lack awareness of the pathogenic bacteria *Salmonella, Campylobacter, E. coli*, and *S. aureus,* which pose health risks to both chickens and consumers. Farmers admitted the presence of harmful bacteria in production; however, they were unaware of the specific species due to insufficient laboratory diagnosis when chickens fall sick or die. A prior study indicated that 56.2% of farmers possessed inadequate knowledge concerning occupational health risks in poultry farms, while 58.7% exhibited unsatisfactory practices related to safety measures aimed at mitigating these risks in the work environment (Abd-Elwahed Ibrahim Mahmoud et al., 2023). The farmers recognized that colibacillosis results from an *E. coli* infection and that white diarrhea indicates salmonellosis; however, they did not know that *Campylobacter* is also a food borne pathogen (Bissong et al., 2022).

The current study reveals that 85.6% of farmers reported that production facilities lacked operational authorization, 89.6% were unregistered with the commission, and 92.7% had not undergone inspection. This may result in bio-security issues, necessitating the mandatory registration of chicken farming enterprises. Similar studies to the present research indicate insufficient monitoring of activities on chicken farms and in animal feed (Bissong et al., 2022; Kimera et al., 2020). Olutumise et al. (2023) reported that mandatory farmer registration, including details such as production scale, will facilitate the formation of groups and cooperative societies, thereby, enhancing business opportunities for farmers. Several authors have highlighted the importance of farmers registering with livestock departments to facilitate continuous monitoring and surveillance of bio-security and husbandry practices (Sawadogo et al., 2023; Siddiky et al., 2022; Tufa et al., 2023).

The study identified significant variations concerning educational level, residential area, and bio-security training ($P < 0.001$). It emphasized that educational level positively influenced bio-security attitudes ($P < 0.001$). The majority of individuals with higher education (93.5%), residing in urban areas and having completed training, exhibited positive attitudes towards bio-security in production. Results from Ethiopia revealed that a significant majority of farmers (94%) held positive attitudes towards bio-security measures that can aid in infection prevention (Tufa et al., 2023). In Nigeria, smallholders who engaged in training demonstrated increased knowledge and improved attitudes regarding bio-security practices for the management of chicken broiler health and well-being (Olutumise et al., 2023).

This study observed a significant correlation between educational level and bio-security practices. Individuals possessing higher education levels demonstrating greater practice in hand washing with soap before and after feeding broilers ($X2= 15.061$, $P= 0.02$) and following toilet use ($X2=20.1$; $P= 0.003$). Kimera et al. (2020) indicated that 92.9% of interviewees possessed insufficient information regarding infection prevention and control related to biosecurity in production, with these findings correlating to educational level ($X2=12.78$, $P=0.005$). The findings showed a significant correlation ($P<0.001$) between biosecurity practices, residential location, and training, revealing good practices among farmers who received training. Sawadogo et al. (2023) also concluded that educational level strongly impacted effective production procedures. Kabeta et al. (2024) revealed that farmers exhibited inadequate biosecurity techniques, lacked foot baths; failed to regularly clean farms, restricted personnel movement to prevent contamination, controlled pests, and did not apply disinfectants on their farms.

Conclusions

The study's findings indicated that chickens were raised in an intensive system, and most smallholders lacked training, authorization, and membership in a chicken producers' association. There were significant positive correlations between educational level and training with knowledge, attitudes, and practices regarding bio-security, indicating that individuals with higher education levels exhibited more effective practices. Many smallholders were unaware of how to utilize protective equipment, refrain from working while unwell, isolate sick chickens from healthy ones, wash hands with soap, or maintain a sanitary workplace to prevent infection. Furthermore, smallholders had negative attitudes toward the cleaning of poultry farms and the meticulous disposal of waste. Smallholders need regular bio-security training on vaccination tactics, disease prevention guidelines, transmission channels, disease vector control, and waste management to improve chicken production knowledge, attitudes, and practices.

RECOMMENDATION

The government should implement biosecurity training programs at different levels based on the educational levels and needs of the producers, with continuous training accompanied by monitoring. The study recommends that smallholders provide chicken infrastructure and equipment, utilize protective gear, and ensure the proper disposal of litter and manure waste to enhance chicken productivity. It also recommends that all farms participate in a collective and register with livestock services for the purposes of biosecurity monitoring and surveillance. The results of this study will be applied to develop suitable policies that will enhance public health and chicken production.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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