

Article

Knowledge Capabilities for Sustainable Poultry Production in Sub-Sahara Africa: Lessons from Southeast Nigeria

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Abstract: The poultry industry in sub-Saharan Africa faces significant sustainability challenges associated with social equity, economic stability, and environmental degradation. As the sector expands due to population and income growth, a major concern remaining is how to ensure a sustainable future for the industry. This paper assessed the knowledge capabilities of poultry farmers for sustainable production using southeast Nigeria as a model region for all riparian regions in sub-Saharan Africa. Sixty poultry farms and 180 participants were sampled. Data were collected from both primary and secondary sources, including relevant literature, participant observations, and in-depth interviews. Data were analyzed with the percentage, bar chart, regression, and Pearson Moment Correlation. Findings revealed that only 13.9% of the respondents had a high knowledge of environmental sustainability. The number of years spent in school ($t = 1.992$; $p = 0.048$), access to veterinary service ($t = 2.161$; $p = 0.032$), and membership in a social organization ($t = 2.306$; $p = 0.022$) were socio-economic factors that significantly influenced knowledge capabilities. Knowledge ($r = 0.252$; $p < 0.005$), rather than income, significantly influenced the use of sustainability practices. Low knowledge of sustainability practices could mean a gross violation on the part of farmers. Specialized programs for educating poultry farmers on the realities of the environmental impacts of their livelihood are paramount.

Keywords: sustainability; sustainable production; poultry farming; environmental sustainability



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1. Introduction

The sustainability of the agrifood system in sub-Saharan Africa has become a pressing challenge [1]. With the population projected to double by 2050 [2], sub-Saharan Africa is home to the world's largest concentration of smallholder farmers, with a low financial base and therefore most vulnerable to the adverse effects of climate change [3]. Agriculture employs about 65% of the region's labor force and contributes to around 32% of its GDP [4]. However, climate change is projected to cause a 10–20% decline in agricultural productivity in the region by 2050, potentially exacerbating food insecurity and poverty [3]. Furthermore, population growth is expected to increase the demand for food, and with decreasing arable land and water resources due to climate change, the sub-region faces the challenge of meeting this demand sustainably [1]. There has been increasing recognition of the importance of sustainable poultry production as a means of addressing these challenges and promoting inclusive economic growth in the sub-region. Amid climate change, increasing

per capita income, and population explosion, poultry farming has increasingly become a very important livelihood activity in sub-Saharan Africa, providing quicker income and animal-source protein for households.

The poultry sector is fast becoming a very important part of the economy of nations through income generation, the diversification of agriculture, and the overall economic development of farm households [5,6]. Poultry production has been recognized as one of the quickest ways to rapidly increase protein supply for the teeming human population. Substantial growth in the production and consumption of poultry eggs and meat is being recorded annually. Estimates show that the total poultry egg and meat production will increase by 657 percent in 2050 and that the aggregate consumption of poultry products will be more than triple [7]. Nigeria is only second to South Africa, producing over 180 million birds and 454 tonnes of meat per year [8]. In southeast Nigeria, over 60% of livestock farmers are engaged in poultry production [9]. However, compared to the USA with 279.8 eggs, Nigeria consumes, on average, only 65 eggs per annum. The average poultry meat consumption is 1.9 kg per capita in Nigeria, compared to 49.3 kg in the USA, 32.98 kg in South Africa, and 7.67 kg in Ghana [10]. Despite the low consumption rate in Nigeria, there is currently a supply deficit, with a projected increase in demand due to population and economic growth among rural and urban populations. It is therefore important to understand how a consumption-led transformed poultry sector could enhance the availability of animal-sourced foods for the food insecure, affect the environment and sustainable use of natural resources, and create new environmental and public health concerns.

Currently, the awareness of climate change is increasing globally with nations becoming more conscious about identifying and reducing climate forcings. There are indications of strong linkages between greenhouse gas formation, the depletion of biodiversity, environmental degradation, and the expansion in livestock production [11]. Although poultry production is relatively more environmentally friendly compared with other livestock groups, its contributions to eutrophication, acidification, and global warming are important environmental concerns [12]. Zhu et al. [13] reported that hen carcasses and manure have emission factors ranging from 45 to 82 kg CO₂-eq./ton of waste. Also, poultry production competes greatly with humans in terms of food production and consumption, as poultry feed is predominantly made of grains, especially wheat, maize, and soybean [14]. About 70% of the cereals produced annually, which could feed up to 3.5 billion people, is consumed by livestock [15]. Consequently, poultry poses strong competition with humans for available grains, along with the environmental risks associated with its management, production, and marketing.

Sustainability in poultry production is as much of an environmental and social issue as it is a food security issue. The direct ecological impact of poultry production has become a great environmental concern in many regions [16]. The urgent need for sustainability in the poultry industry has necessitated multi-national food companies becoming more concerned, thereby placing stricter measures throughout their procurement chains. The interest in sustainable production is broader than just environmental concerns [17]. Environmental sustainability relates to minimizing the impact of poultry production on the environment. This is achieved through efficient production and management practices, such as improved breeding, feed production, waste management, emissions management, water usage, and supply chain distribution [11]. On the other hand, social sustainability broadly relates to food security, food safety, health, and the welfare of birds and farm workers [11]. Specifically, the social pillar of sustainability aims to ensure the production of safe poultry products that are adequate to feed the growing population without constituting public health concerns. Social sustainability emphasizes the well-being of people, including employees, customers, industry professionals, and the global community [18] and that of the animals. The economic pillar, on the other hand, relates to economic efficiency in terms of expansion in scale, technology, and overall enterprise management to ensure a consistent supply of poultry products to cater for the growing human population. Incul-

cating all three pillars first requires substantial knowledge of the best practices to ensure sustainability. In other words, knowledge is required to modify production practices to fit with environmental, social, and economic sustainability in poultry production.

Studies [19–22] on smallholders' sustainability practices in sub-Saharan Africa have mainly emphasized the financial implications of innovative technologies, which are usually beyond the reach of smallholders. However, some sustainable production practices may not necessarily require an extra expenditure on the part of the farmer, but would rather require that the farmer is aware of its applicability in ensuring the environmental, social, and economic sustainability of the farming enterprise. The knowledge of environmental, social, and economic sustainability is necessary to ameliorate the fallout conditions arising due to the impact of climate change and the increase in demand for poultry meat and eggs. Knowledge is therefore a major source of competitive advantage. It is a very important factor in building the resilience of the farm enterprise through informed decision-making. Knowledge capabilities refer to the abilities of an individual to effectively perform the knowledge processes and activities on which a system's success depends. Knowledge capabilities are the bedrocks that ensure the effectiveness of any system [23]. It is an essential factor in production, next to land, labor, and capital [24]. It relates to all the information, skills, and experiences gathered in the process of understanding and working with things, which provide the basis for engaging new information, ideas, and experiences needed to solve new and emerging problems. It provides a structure for appraising and incorporating new ideas, experiences, and information [25]. Knowledge capability is a function of information, ideas, skills, and experience garnered by an individual or firm, which could influence the adoption of sustainability principles in the production process. The question is as follows: how knowledgeable are poultry farmers of environmental, social, and economic sustainability? This paper, therefore, fills the intellectual gap on the influence of knowledge in the use of sustainable production practices in poultry production.

Hypothesis 1 (H1). *Socio-economic factors do not have a significant influence on the knowledge capabilities of poultry farmers regarding sustainable production.*

Hypothesis 2 (H2). *There is no significant relationship among knowledge capabilities, income, and the use of sustainable production practices in poultry production.*

2. Materials and Methods

The study was conducted in Southeast Nigeria. The region comprises five states: Anambra, Abia, Ebonyi, Enugu, and Imo. The population for the study comprised medium- and large-scale poultry farmers (having up to 500 birds and making use of hired labor). Respondents were selected in four stages. First, three states (Anambra, Imo, and Enugu) were randomly selected from the five states in the region. Thereafter, two agricultural zones (AZs) were purposively selected from each of the states selected. In the third stage, two blocks were purposively selected from each of the four AZs selected from Anambra and Imo States (giving a total of 8 blocks from the two states), while five blocks were purposively identified from the two AZs selected in Enugu State to give a total of 13 blocks. In the fourth stage, accidental and snowball sampling techniques were used to select five poultry farms from each block giving a total of 65 farms. However, only responses from (60) poultry farms were fully completed and used for analysis. In each farm, one management staff and two farm workers were selected and interviewed. This gave a total of 180 respondents used for the study. Data were collected using a structured interview schedule with open-ended questions. The reliability of the instrument was tested using the Cronbach Alpha coefficient for internal consistency. The instrument was validated by experts in the Department of Agricultural Extension, University of Nigeria, Nsukka.

Personal data, such as age (in years), gender (male or female), marital status (single, married, divorced/separated, widowed), education (number of years spent in school), poultry farming experience (years), household size (number of persons currently in the

household), household monthly income (naira), estimated annual earnings from poultry production (naira), access to veterinary services (number of times in the past one year), access to extension service (number of times in the past one year), membership to the social organization(s), and access to credit facilities, were collected. Knowledge capabilities on sustainable production (KCSP) were collected by asking respondents to state what they know about each of the environmental, social, and economic aspects of sustainability practices. Individual responses were collated and scored. A correct response was scored '1', while an incorrect response was scored '0'. A composite score was generated for each respondent and used to categorize them on their level of knowledge into low (1–10 composite score), moderate (11–20 composite score), and high (≥ 21 composite score) knowledge based on the three aspects of sustainable production. Respondents were thereafter asked to indicate which of the sustainable practices they used in their farms. A composite score was also generated for each respondent based on the sustainable poultry production practices (S3P) used. Data generated were analyzed with percentages, and bar chart while the hypotheses were analyzed using a linear Regression Model and Pearson Moment Correlation. The regression model is in the form below:

$$Y = \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 \dots + \beta_{12}X_{12} + U$$

where: Y = knowledge capabilities (Knowledge score for each respondent);

$\beta_1 - \beta_{15}$ = regression coefficient;

X1 = age (years);

X2 = gender (male = 1, female = 0);

X3 = marital status [married = 1 (living with a spouse), not married (not living with a spouse) = 0];

X4 = educational level (actual number of years spent in formal education);

X5 = years of experience in poultry farming (years);

X6 = size of household (number of people living under the same roof and having at least one meal per day together);

X7 = access to extension in the last one year (yes = 1, otherwise = 0);

X7 = access to veterinary services in the last year (yes = 1, otherwise = 0);

X8 = belonging to a social organization (yes = 1, otherwise = 0);

X9 = access to credit facilities in the last 1 year (yes = 1, otherwise = 0);

X11 = monthly household income (naira);

X12 = annual income from poultry production (naira); and

U = error term

The composite scores for the 'S3P' use, the knowledge capabilities, and the continuous variables of farmers' income were used in the correlation analysis.

3. Results

3.1. Knowledge Capabilities for Environmental Sustainability Practices

Findings reveal that 92.2% of the respondents indicated that isolation of farms from residential areas can be used as a mitigation measure to reduce air pollution, while 91.1% of the respondents indicated that offensive odors from poultry waste cause serious environmental pollution problems (Table 1). Similarly, the majority (89.4%) of the respondents indicated that poor manure management in poultry production contributes to the environmental impact, while 88% of the respondents noted that poultry waste encourages the breeding of rodents in the environment. A good proportion (87.2%) of the respondents indicated that the careless disposal of waste from poultry slaughter points results in disease ailments on poultry farms, while 85.6% specified that the accumulation of gases in poultry facilities causes serious air pollution. About 84% of the respondents indicated that adequate ventilation can be used as a mitigation measure in reducing air pollution in poultry farms.

Table 1. Knowledge capabilities for environmental sustainability.

Parameters of Sustainability in Poultry Production	Frequency	Percentage
Environmental Sustainability		
Poultry production is associated with environmental impacts, such as climate change	61	33.9
Poultry production is associated with the acidification of rain	20	11.1
Poultry production causes eutrophication (excessive growth of intrusive microorganisms, such as algae blooms) in nearby streams	56	31.1
Disposing of wastes from poultry farms directly into the environment contaminates water bodies, such as rivers, lakes, and ground waters	71	39.4
Poultry production leads to nitrogen emissions, such as ammonia (NH ₃)	143	79.4
Chicken production contributes to environmental impacts through the emissions of fine particulate matter	97	53.9
Chicken production contributes to climate change through the emissions of black carbon emissions	55	30.6
The production and transport of poultry feed contribute to the build-up of greenhouse gases	57	31.7
Using feed additives (amino acids and enzymes) can enhance environmental sustainability in poultry production	80	44.4
Poultry production on-farm emissions are the main factors contributing to environmental impacts	110	61.1
A major environmental impact of poultry production results in feed production and consumption	98	54.4
Intensification in cereal production for poultry feed has led to the depletion of forests	72	40.0
The intensive use of fertilizers in soybean production has resulted in pollution of water resources	68	37.8
The emission of carbon dioxide through the burning of fossil fuels in poultry farms and slaughterhouses has environmental impacts	91	50.6
Carbon dioxide emitted during the transportation of processed poultry products has environmental impacts	85	47.2
Poor manure management in poultry production contributes to environmental impacts	161	89.4
Accumulation of gases in poultry facilities causes air pollution	154	85.6
Reducing stocking density can reduce air pollution in poultry farms	120	66.7
Adequate ventilation can enhance air quality in poultry farms	152	84.4
Wastes from poultry contain pathogens and natural and synthetic hormones, which can enter the local soil	141	78.3
The isolation of farms can be used as a mitigation measure to reduce air pollution	166	92.2
Poultry litter contains high concentrations of water-soluble elements, which are readily transported in the farm run-off	102	56.7
Offensive odors from poultry wastes cause serious environmental pollution problems	164	91.1
Poultry wastes promote the build-up of insects and flies in the environment	137	76.1
Poultry wastes encourage the breeding of rodents in the environment	158	87.8
The careless disposal of waste from poultry slaughter points results in disease ailments in poultry farms	157	87.2

Similarly, 79.4% of the respondents indicated that poultry production leads to nitrogen emissions, such as ammonia (NH₃), while 78.3% of the respondents noted that poultry waste contains pathogens and natural and synthetic hormones, which can enter local soil.

On the other hand, 76.1% indicated that poultry wastes promote the build-up of insects and flies in the environment.

3.2. Knowledge Capabilities of Poultry Farmers Regarding Social Sustainability

Findings in Table 2 show that 98.3% of the respondents indicated that improving the work conditions of the poultry farm and the health of farm workers is related to social sustainability, while 97.8% specified that ensuring decent salaries for poultry workers is an important aspect of social sustainability. A good proportion (94.4%) of the respondents specified that the inhalation of poultry dust (feathers, dried manure, feed, and litter materials) by workers increases the risk of respiratory problems, while 93.9% of the respondents indicated that birds are exposed to various stressors, such as heat stress, during transport. Similarly, 93.9% of the respondents noted that a poultry farm that employs both men and women is socially sustainable.

Table 2. Knowledge capabilities of poultry farmers regarding social sustainability.

Parameters of Sustainability in Poultry Production	Frequency	Percentage
Social Sustainability		
Improving the work conditions of the poultry farm and the health of farm workers is related to social sustainability	177	98.3
Social sustainability includes ensuring health insurance for workers	155	86.1
Ensuring decent salaries for poultry workers is an important aspect of social sustainability	176	97.8
Poultry workers and their families members are consistently exposed to infections from antibiotic-resistant bacteria	132	73.3
Elevated ammonia concentrations in poultry farms affect the workers' health negatively and have negative effects on the health of the workers	154	85.6
The health of poultry birds is negatively affected when exposed to high ammonia concentrations in poultry farms	148	82.2
The inhalation of tiny particles of feathers and skin of birds and other poultry-related materials, such as dried manure, feed, and litter, increases the health risk of farm workers	170	94.4
Poultry dust affects the quality of air for residents close to poultry farms	138	76.7
Workers in poultry houses are susceptible to zoonosis through direct contact with infected birds	135	75.0
The killing of day-old chicks of the layers line is an animal welfare issue	102	56.7
Reducing thirst and hunger while making feeding pleasurable for the birds is important for social sustainability	143	79.4
The provision of comfortable resting areas (such as shade/shelter or suitable housing) for poultry birds is related to social sustainability	158	87.8
Reducing threats and unpleasant restrictions on birds' behavior is related to animal welfare	160	88.9
Minimizing pain and other aversive experiences in poultry birds is an important aspect of animal welfare	159	88.3
Beak trimming causes short-term pain in birds	146	81.1
Restricted natural behaviors of poultry birds in conventional cages is a social sustainability issue	137	76.1

Table 2. Cont.

Parameters of Sustainability in Poultry Production	Frequency	Percentage
Limiting the poultry birds' ability to perform their highly motivated behaviors in conventional cages is a sustainability issue	131	72.8
The transition from a cage system to a non-cage system bears the increased risk of feather pecking and cannibalism among poultry birds	139	77.2
Litter conditions cause leg problems for poultry birds	143	79.4
Expanding the space of the pen improves the welfare of layers and broilers	131	72.8
Environmental enrichment increases the animal's behavioral freedom and leads to enhancement of the biological function	110	61.1
Stocking density has a significant effect on broiler welfare	164	91.1
A crowded poultry house makes the birds move a shorter distance per hour and show less natural behavior (pecking, scratching, walking behavior, etc.)	163	90.6
Birds are exposed to various stressors, such as heat stress, during transport	169	93.9
The inadequate catching and transport of broiler chickens affect their welfare	157	87.2
Slaughter operations (stunning, killing, etc.) performed on birds may have a negative effect on product quality	124	68.9
Improving animal welfare is costly	144	80.0
A poultry farm that employs both men and women is socially sustainable	169	93.9

On the other hand, 91.1% of the respondents indicated that stocking density has a significant effect on broiler welfare, while 90.6% of the respondents expressed that crowded poultry houses make the birds move a shorter distance per hour and show less natural behavior, such as pecking, scratching, and walking behavior. A good proportion (88.9%) of the respondents specified that reducing threats and unpleasant restrictions on birds' behavior is related to animal welfare, while 88.3% expressed that minimizing pain and other aversive experiences in poultry birds is an important aspect of animal welfare. About 88% of the respondents indicated that the provision of comfortable resting areas (such as shade/shelter or suitable housing) for poultry birds is related to social sustainability (87.8%), while 87.2% of the respondents expressed that the uncomfortable catching and transport of broiler chickens affect their welfare.

Also, 86.1% of the respondents specified that providing health insurance for workers is related to social sustainability; about 86% of the respondents expressed that elevated ammonia concentrations in poultry farms pose detrimental health effects on the workers, while 82.2% of the respondents noted that the health of poultry birds is negatively affected when exposed to high concentrations of ammonia in poultry farms. Also, about 81.1% of the respondents know that beak trimming causes short-term pain in birds, and a good proportion (80.0%) of the respondents indicated that improving animal welfare is costly.

3.3. Knowledge Capabilities of Poultry Farmers Regarding Economic Sustainability

As shown in Table 3, 99.4% of the respondents indicated that profitability (the income received per unit of investment) and the productivity of poultry farms are important factors of economic sustainability. About 98.9% of the respondents specified that the capability of poultry farms to pay workers' salaries is related to economic sustainability, while 97.2% of the respondents indicated that the ability of poultry farms to afford the cost of production is associated with economic sustainability (Table 3).

Table 3. Knowledge capabilities of poultry farmers regarding economic sustainability.

Parameters of Sustainability in Poultry Production	Frequency	Percentage
Economic Sustainability		
The major determinant of economic sustainability is the farmer's income	150	83.3
Profitability (the income received per unit of investment) is an important factor of economic sustainability	179	99.4
Poultry farms with high liquidity (the easiness in the conversion of farm assets to cash) are economically sustainable	136	75.6
The productivity of poultry farms is an important factor in economic sustainability	179	99.4
The cost of farm inputs (such as feed, poultry house, vaccination, and breed) has a significant effect on the profitability of poultry production	172	95.6
An economically sustainable poultry farm must be able to meet the individual economic needs of farmers, farmworkers, and the farm family	149	82.8
An economically sustainable farm ensures financial stability	161	89.4
An economically sustainable farm allows for an improved economic return on used resources	155	86.1
A sustainable farm should be able to manage all farm activities most economically	155	86.1
An efficient poultry production process is associated with economic sustainability	155	86.1
Mortality reduces economic sustainability in the poultry business	159	88.3
feed constitutes about 60% of the total cost of poultry production	150	83.3
Reducing stocking density decreases production income in poultry production	132	73.3
The ability of poultry farms to afford the cost of production is associated with economic sustainability	175	97.2
The ability of poultry farms to accept the risk and uncertainties associated with poultry production is related to economic sustainability	129	71.7
The capability of poultry farms to pay workers' salaries is related to economic sustainability	178	98.9

A good proportion (95.6%) of the respondents identified that the cost of farm inputs (such as feed, poultry house, vaccination, and breed) has a significant effect on the profitability of poultry production, while 89.4% of the respondents noted that an economically sustainable farm ensures financial stability (Table 3). About 88.3% of the respondents noted that mortality increases production costs (through increased production cost per bird), while 86.1% of the respondents indicated that an economically sustainable farm allows for an improved economic return on resources used, a sustainable farm manages all activities most economically, and efficiency in the poultry production process is determined by economic sustainability (Table 3).

Results in Table 3 show that the majority (83.3%) of the respondents indicated that feed constitutes about 60% of the total cost of poultry production and that farmers' income determines the economic sustainability of the poultry business. Similarly, about 82.8% of the respondents indicated that an economically sustainable poultry farm must be able to meet the individual economic needs of farmers, farmworkers, and the farm family (Table 3).

3.4. Levels of Knowledge Capabilities

Figure 1 shows that a very small proportion (13.9%) of the respondents had high knowledge of environmental sustainability, while the majority (80.6%) had moderate knowledge, and 5.6% had low knowledge of environmental sustainability. However, the majority (73.3%) of the respondents had high knowledge of social sustainability while 25.6% had moderate knowledge, and only 0.6% of the respondents had low knowledge of social sustainability. Conversely, 97.8% had high knowledge of economic sustainability,

and only 2.2% had moderate knowledge of the economic sustainability aspect of poultry production (Figure 1).

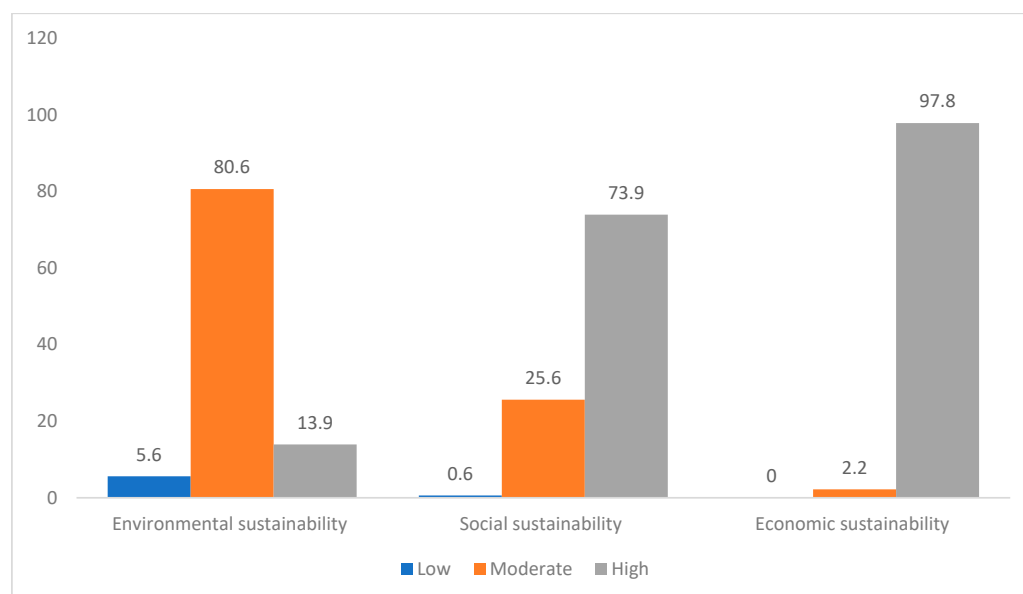


Figure 1. Levels of knowledge capabilities for sustainable poultry production practices.

3.5. Socio-Economic Factors Influencing Respondents' Knowledge Capabilities

From the regression estimate (Table 4), the number of years spent in school ($t = 1.992$; $p = 0.048$), access to veterinary service ($t = 2.161$; $p = 0.032$), and membership in a social organization ($t = 2.306$; $p = 0.022$) had a significant effect on respondent knowledge capabilities (Table 4). Findings show no significant relationship between knowledge capabilities and age ($t = -0.457$; $p = 0.648$), sex ($t = -0.054$; $p = 0.957$), marital status ($t = 0.073$; $p = 0.942$), year of experience in poultry farming ($t = 1.188$; $p = 0.236$), size of household ($t = -0.534$; $p = 0.594$), access to extension ($t = 1.934$; $p = 0.058$), access to credit ($t = -0.129$; $p = 0.897$), estimated monthly income ($t = -1.197$; $p = 0.233$), and annual income from poultry production ($t = 1.591$; $p = 0.113$) (Table 4). The null hypothesis is therefore accepted for these factors.

Table 4. Socio-economic factors influencing knowledge capabilities.

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	T	Sig.
Constant	45.626	2.822		16.169	0.000
Age	−0.028	0.062	−0.045	−0.457	0.648
Sex	−0.059	1.103	−0.004	−0.054	0.957
Marital status	0.092	1.262	0.007	0.073	0.942
Number of years spent in school	0.256	0.129	0.156	1.992	0.048
Years of experience in poultry farming	0.113	0.095	0.108	1.188	0.236
Size of household	−0.111	0.209	−0.041	−0.534	0.594
Access to extension	3.611	1.867	0.295	1.934	0.058
Access to veterinary service	2.507	1.160	0.164	2.161	0.032
Social organization	2.556	1.108	0.179	2.306	0.022
Access to credit	−0.238	1.842	−0.010	−0.129	0.897
Estimated monthly income	-1.696×10^{-5}	0.000	−0.226	−1.197	0.233
Annual income from poultry production	1.677×10^{-6}	0.000	0.293	1.591	0.113

Dependent variable: knowledge capabilities of respondents; $p = 0.05$; $R = 0.333$; $R^2 = 0.111$; adjusted $R^2 = 0.052$.

The R squared value is the proportion of variability in the dependent variable (knowledge capabilities) explained by the changes in the independent variables (socio-economic factors) as expressed by the regression model. The adjusted R squared (0.052) was the estimated r^2 (coefficient of determination) for the population. Therefore, the number of years spent in school, access to veterinary service, and membership in social organizations were able to explain approximately 5.2% of the variance in the knowledge capabilities of respondents.

3.6. Relationship among the Use of Sustainable Production Practices (S3P), Knowledge Capabilities, and Income of Poultry Farmers

Table 5 shows the correlation result among the use of 'S3P', knowledge capabilities, and income of poultry farmers. Results show that there is a significant positive correlation ($r = 0.252$; $n = 180$; $p > 0.005$) between knowledge capabilities and the use of 'S3P'. However, results show that there is no significant relationship among income from poultry production ($r = 0.02$, $n = 180$; $p > 0.05$), broader household income ($r = 0.029$, $n = 180$; $p = 0.05$), and use of 'S3P'.

Table 5. Correlation between knowledge capability and use of SPPP.

		Use of SPPP
Knowledge capability	Correlation coefficient	0.252 **
	Sig. (two-tailed)	0.001
	N	180
Income from poultry production	Correlation coefficient	0.002
	Sig. (two-tailed)	0.700
	N	180
Household income	Correlation coefficient	0.029
	Sig. (two-tailed)	0.979
	N	180

** Correlation is significant at the 0.01 level (2-tailed).

4. Discussion

4.1. Knowledge Capabilities of Poultry Farmers for Environmental Sustainability Practices

The state of poultry waste management in sub-Saharan Africa, as a key environmental sustainability issue, varies widely across the region. In some areas, there are well-established systems for the collection, treatment, and disposal of poultry waste. In other areas, however, there is a lack of infrastructure and resources for waste management, leading to the uncontrolled dumping of waste in open areas, rivers, and other water bodies. While most studies focus more on solid and liquid poultry waste, including sludge, abattoir waste, shells, bedding material, manure, feathers, feed, hatchery waste, and mortality [26], key informants in this study noted bad odor, 'gaseous waste' resulting from the poor management of poultry wastes, as severely impacting both the immediate and external environment of the farm, thereby jeopardizing human and animal welfare and the right to quality air. Evidence has shown that adequate ventilation in poultry houses is aimed at removing the undesirable concentration of pollutants and odor [23,27,28]. Therefore, the environmental condition and welfare of poultry birds and farm workers will be improved under a well-ventilated poultry house ensuring maximum productivity of the birds and preventing occupational exposure to harmful gases.

In line with this, the findings of this study reveal that farmers in southeast Nigeria were knowledgeable about the importance of siting poultry farms in isolated areas and away from the main public roads, markets, and schools to avoid offensive odors. Poultry farms in sub-Saharan Africa are increasingly being sited in isolated areas to reduce their impact on the environment and nearby communities. For instance, a large poultry farm was established in a remote area of Ogun State in southwest Nigeria in 2017 to prevent complaints from nearby residents about the smell and noise from the farm [29]. Similarly,

in Ghana, a poultry farm was established on the outskirts of Kumasi in the Ashanti region, away from residential areas and main roads to reduce the impact on the environment and the community [30]. Additionally, several large poultry farms have been established in isolated areas away from residential areas and main roads in Kenya, such as in Nakuru town and the outskirts of Nairobi [31]. However, they lack the knowledge and technicality to sustainably use poultry waste.

One such technicality is the post-farm handling of poultry manure waste. The indiscriminate dumping of poultry wastes on soils can cause serious environmental impacts, such as climate change, eutrophication, food safety concerns, and other environmental degradation processes associated with poultry production. Findings of this study showed that poultry farmers were oblivious to the fact that if poultry waste is not properly treated, it can contain high levels of pathogens, including *Salmonella*, *E. coli*, and *Campylobacter*, which can contaminate soil and water sources and pose a significant risk to human health. It is important to note that the judicious and sustainable application of poultry manure based on the soil nutrient requirements of crops will help to reduce the problem of eutrophication caused by washing away excess soil nutrients down the waterways by runoff water and ameliorating food safety concerns. In furtherance, studies have also shown that organic manure application in soils leads to greenhouse gas (e.g., CO_2 , N_2O , and methane) emissions [32,33]. When manure is not recycled, it emits quite a large quantity of CO_2 , N_2O , and CH_4 , which are very important greenhouse gases. However, recycling waste into fertilizers for crop farms and fermentation in biogas plants can reduce emissions to nearly zero [34].

Additionally, poultry wastes attract rodents and flies, which could transmit parasites and pathogens to the poultry flock [28]. Farmers who handle poultry waste or work in close proximity to it may be at increased risk of exposure to these disease vectors, as well as to the pathogens they carry. Farmers need to take appropriate precautions to minimize their risk of exposure, such as wearing personal protective equipment, practicing good hygiene, and properly storing and disposing of poultry waste, including regular removal and disposal, which can help reduce the risk of disease transmission.

Overall, the poultry farmers did not have good knowledge of environmentally sustainable practices, implying that they could be engaging in practices that have serious detrimental effects on the environment. While there have been significant efforts to promote the adoption of innovative technologies and best environmental practices in sub-Saharan Africa, there has been less emphasis on enhancing the environmental sustainability knowledge necessary to support the sustainable use of these technologies and practices.

4.2. Knowledge Capabilities of Poultry Farmers Regarding Social Sustainability

One key aspect of sustainability in poultry production that is often overlooked in current efforts is the need for context-specific knowledge capabilities for the social aspect of the poultry value chain. Sub-Saharan Africa is a diverse region, with a wide range of ecological, social, traditional, religious, and cultural conditions that can significantly influence the implementation of social sustainability in poultry production. Therefore, to ensure that sustainable poultry production practices are effective in the region, it is necessary to develop context-specific knowledge capabilities that account for local conditions, constraints, and opportunities. Key informants and farm workers in southeast Nigeria indicated that ensuring the welfare of farmers and farm workers, as well as that of the birds, also bearing in mind the welfare of the eventual consumers of the poultry products, is very crucial. This aligns firmly with Vaarst et al. [35], who noted that ensuring the fairness of employment contracts, such as health insurance, decent salaries, and improved bargaining power, are critical parts of social sustainability. This implies that poultry farmers or owners should be cautious in the way they handle employees and should be willing to improve the welfare of their workers by ensuring fairness in employees' contracts and salary.

Birds and poultry workers are susceptible to health complications when subjected to elevated concentrations of ammonia in poultry houses [36]. Also, tiny particles of feathers,

the skin of birds, and other poultry-related materials, such as dried manure, feed, and litter, increase the health risk of farm workers [37]. Ensuring adequate ventilation in poultry houses can help to enhance the safety of poultry workers while improving animal welfare for optimum production. Therefore, government agencies and development practitioners should provide the right incentives and consciously pursue the grassroots implementation of equitable and fair poultry operations in sub-Saharan Africa. In furtherance, stocking density is an important aspect of welfare concern [38]. Thus, farmers should handle their birds properly to ensure bird welfare using the recommended floor space and stocking density. Lessons from Southeast Nigeria revealed that beak trimming inflicts pain on birds. Mench and Rodenburg [37] noted that beak trimming is a welfare issue through the short-term pain it causes to birds. It could be inferred that beak trimming breaches animal welfare ethics especially when poorly conducted, and it could also cause beak malformation in birds.

Nevertheless, poultry farm owners and CEOs in the study site argue vehemently that beak trimming is a crucial aspect of making poultry production more profitable through a reduction in feather pecking, cannibalism, and the destruction of eggs. They continued by noting that animal welfare ethics were poorly defined and are mere statements that are emotion-based and not science-based. The level of education and religion of the informants further hone their decisions to override poultry welfare as they believe they have dominion over animals. Therefore, this study synthesizes that more research should be conducted to further reveal the interrelationship between cultural and religious views and the implementation of poultry welfare ethics in sub-Saharan Africa.

The results of this present study clearly show that a good number of farmers and farm workers have good knowledge of human and animal welfare. Nevertheless, it is important to note that they only implement welfare ethics that enhance profitability and thus may be unwilling to follow and implement policies that strengthen human–animal welfare practices that are accompanied by economic consequences. Therefore, it is important to provide incentives to farmers and farm owners as motivation to implement welfare ethics.

4.3. Knowledge Capabilities of Poultry Farmers Regarding Economic Sustainability

For a farm to be economically sustainable, it must ensure reasonable economic return on the use of resources and allow for financial stability [39]. The efficient use of farm resources and ensuring the productivity of farm enterprises will boost farmers' income, which could improve the standard of living of the farmers and aid in farm expansion. Al-Sharafat et al. [40] noted that profitability is the main factor associated with economic sustainability. The awareness of poultry farmers about the factors associated with economic sustainability may spur them to seek alternative farm inputs and technologies, which will reduce their cost of production and maximize profit. van Asselt et al. [41] found that the sustainability of a poultry enterprise was determined by farm income. It could be inferred that farm income is fundamental in ensuring the sustainability of a poultry enterprise.

Therefore, a sustainable poultry enterprise must meet individual economic needs [39]. This means that once the economic needs of the poultry farm owners and their workers are met, they will be committed to improving their poultry enterprise, increasing the number of sustainable practices used without any form of financial pressure. Overall, findings show that the poultry farmers were quite knowledgeable on how to maximize profit and thus ensure the economic sustainability of the poultry enterprise. This could be related to the relatively high literacy level of the poultry farmers and the experiences they have garnered from their relatively large poultry farm size. Large poultry farms always ensure a considerable level of economically sustainable production practices to maximize profit and stay afloat.

4.4. Socio-Economic Factors Influencing Respondents' Knowledge Capabilities

The result of Hypothesis 1 (H1) adopted for this study shows that the number of years spent in school had a significant positive relationship with the knowledge capabilities of the

respondents. It could be inferred that the higher the educational level of poultry farmers, the higher their knowledge level of sustainable poultry production. Therefore, acquiring more formal education increases the knowledge capabilities of poultry farmers. Education is an important factor in enhancing the knowledge capabilities of poultry farmers regarding environmental, social, and economic sustainability in poultry production. Similarly, access to veterinary services had a significant positive relationship with the knowledge capabilities of respondents. This finding implies that the more access to veterinary services by poultry farmers, the higher their knowledge capabilities regarding environmental, social, and economic sustainability in poultry production. It could therefore be inferred that veterinary doctors are also playing the role of extension agents in providing information on sustainable poultry production to poultry farmers. Veterinary service providers are therefore important actors in sustainable poultry production. Furthermore, membership in social organizations had a significant positive effect on the knowledge capabilities of respondents. This implies that the more social organizations to which the respondents belonged, the greater their knowledge capabilities regarding sustainability in poultry production. Information on innovations, technologies, and sustainable production practices could be spread through intrapersonal channels in social groups where farmers could leverage, and thus improve, their knowledge capabilities. Social organizations are therefore an important platform for enhancing poultry farmers' knowledge of sustainable production. The null hypothesis is therefore rejected for the number of years spent in school, access to veterinary service, and membership in social organizations.

4.5. Relationship among the Use of Sustainable Poultry Production Practices (S3P), Knowledge Capabilities, and Income of Poultry Farmers

Remarkably, the results of Hypothesis 2 (H2) show a significant positive correlation between knowledge capabilities and the use of sustainable poultry production practices. However, the use of 'S3P' has no significant relationship either with income from poultry production or the broader household income. This implies that knowledge, rather than finance, influences whether poultry farmers will adopt sustainable production practices. Knowledge is therefore an indispensable factor in the sustainability discourse. This means that poultry farmers can adopt sustainable practices they know about whether there are other incentives, such as finance, policy, etc. Therefore, farmers will be willing to use sustainability practices if they have full knowledge of those practices and this will naturally make them willing to adopt the practices. Gaining the willingness of farmers to engage in environmentally friendly solutions can lead to a more lasting effect. This willingness can be achieved when farmers fully understand the effects of their actions. Such understanding can only be achieved by gaining the right knowledge [42]. This knowledge will therefore drive a stable and lasting positive attitude leading to the embeddedness of actions. On the other hand, low knowledge could mean false perceptions and invariably lead to wrong attitudes and bad practices. A poultry sector that can provide for the current generation while assuring a sustainable production system for the future generation would require that the producers engage in new capacity development. Such capacity-building could prioritize knowledge as a basic tool for practice. Ecological awareness is a fundamental factor in the adoption of sustainable solutions.

5. Conclusions

From the results, poultry farmers had high knowledge of social and economic sustainability. However, they do not have good knowledge of environmental sustainability practices in poultry production systems. The number of years spent in school, access to veterinary services, and membership in social organizations were the socio-economic variables influencing the knowledge capabilities of poultry farmers regarding sustainability. The knowledge capabilities of poultry farmers positively influenced their use of sustainable production practices. To enhance the environmental sustainability of poultry production systems, there is a need to educate the farmers on the sensitive, latent

environmental impacts of poultry production, which have been associated with insidious environmental degradation, and also develop a system for enumerating holistically the level of environmental effects of poultry production.

Contrary to the general opinion that income influences the adoption of farm-level innovative practices, the current study has proven that it is not always so in sustainability studies. The paper concludes that knowledge (rather than income) influences poultry farmers' use of sustainable production practices. Knowledge, therefore, adds to the theoretical basis for adjudging sustainability assessment approaches. The significant positive relationship between knowledge and use of 'S3P' is a clear indication that the awareness of sustainability issues is paramount for the poultry sub-sector in sub-Saharan Africa. Education programs for poultry farmers could therefore yield a greater and better dividend in terms of compliance with sustainability principles compared to finance. The practical implication is that knowledge should be a fundamental consideration in actions aimed at fostering sustainable production in the poultry industry. However, it is important to note that the implementation of sustainable practices in poultry farms does not necessarily result in a 'win-win' scenario as there could be many complex intertwined issues cutting across different socio-economic and socio-cultural boundaries that could affect the trend. Ensuring sustainability in poultry production is therefore strictly location/context-specific, and a practice that is sustainable in location A may be unsustainable in location B. In view of this, efforts should be deployed to accelerate the adaptation of global sustainable poultry practices and policies to fit into local contexts and consciously pursue local actions in grassroots implementations. There is therefore a need for further research on the location-specific drivers, as well as locally adaptable actions, for sustainable poultry production in sub-Saharan Africa.

The paper recommends that both public and private extension-service-providers should include environmental impacts and sustainable poultry production in their toolkits and vigorously pursue its grassroots implementation among poultry farmers. Development agencies, policymakers, civil society organizations, the private sector, and other climate and environmental enthusiasts and sustainability promoters should target awareness and knowledge-building opportunities as a very viable and cost-effective entry point for poultry farmers. This will enhance the dissemination and production of information, which could help poultry farmers make informed farm-level decisions and foster the use of sustainable production practices.

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