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Gendered Awareness of Pig and Poultry Farmers on the Potential of Black Soldier Fly (*Hermetia illucens*) Farming in Kenya

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Abstract: Given the need to boost food production while guaranteeing environmental sustainability, the black soldier fly (BSF) (*Hermetia illucens* (L.), *Diptera: Stratiomyidae)* is gaining traction worldwide as an alternative protein source. In Kenya, BSF production and its use as a feed component is an emerging business, but farmer awareness of the potential use of BSF in animal feed has received limited attention. This study examined the factors influencing farmer awareness of insect farming and its usefulness as ingredient in livestock feed from a gender perspective. The analysis employed a mixed-methods approach by combining binary logistic regression analysis using cross-sectional survey data from a sub-sample of 235 pig and poultry farmers and content analysis from in-depth phone interviews. The study was implemented in Kiambu County, Kenya. About 44% of the farmers were aware of the use of black soldier fly in the animal feed industry, of which 46.72% were female, and 41.59% were male. From the results, years of education, the number of chickens owned, and membership in agricultural groups significantly influenced male and female farmers' awareness. In addition, age and the number of pigs owned significantly influenced female farmers' awareness. The results suggest that these factors are important to consider when strategies are developed to create awareness of BSF farming. Lessons learned from this study will inform BSF dissemination strategies to better target potential men and women BSF producers, influence their decision-making ability and improve information flows between scientists and producers.

Keywords: awareness; black soldier fly; logistic regression; smallholder farming; gender-sensitivity

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1. Introduction

Given the expanding population and consumer demand, there is a need to improve food production while maintaining environmental sustainability. Increasing livestock production in developing nations has a favourable influence on food and nutrition security as well as poverty reduction [1]. On the other hand, modern animal production methods are limited by lack of feed protein in terms of quality and quantity, especially in developing economies. Furthermore, protein sources are expensive hence raising the cost of feeds in the market. High feed costs work against efforts to commercialize animal production and to meet the increasing demand for protein rich food.

In Kenya, the animal feed industry acquires its protein ingredients from fish meal, *Omena* (*Rastrineobola argentea*), soybean, seed cakes, and several other grain products. Currently, *Omena* and soybeans are the primary protein sources in the feed industry. However, their supply is constrained by high market prices, poor quality, and unavailability during certain periods of the year. In East Africa, marine overexploitation of Lake Victoria has reduced *Omena* availability for fishmeal production [2]. Moreover, there is stiff competition in consumption of these protein sources because *Omena* is used as livestock feed and consumed as human food as well. Poultry and pig farmers indicate that the cost of feed is about 60–70% of the total production costs, and the protein component the most expensive ingredient [3]. For environmental and cost reasons, it is not sustainable to continue relying on *Omena* and soybean as a source of protein in animal feed production [4]. Rearing of black soldier fly (BSF) can solve this problem and it has added benefits: BSF feed on organic waste and recycle waste into high-quality protein [5,6]. The crude protein content levels of dried BSF larvae range between 42 and 63% [7]. Insects also are a good source of micronutrients, fatty acids, and amino acids which are components added to most animal feed [8]. BSF has been successfully reared on a wide variety of substrates and can be fed on low-value organic waste locally sourced from the food industry, agriculture, household food waste, and market remains. In addition, chicken manure and swine waste are successfully used as BSF substrate [9,10]. The left-over frass can be composted to organic fertilizer and improve food production. As cyclic process BSF production has a low environmental impact and can even contribute to carbon storage when bio-fertiliser is used to improve soil organic matter. Organic fertilizer produced from BSF frass can reduce use of chemical fertilizers and provide soil fertility improvement services without leading to additional environmentally unsustainable agriculture practices [11,12]. All these benefits contribute to the increase of interest in BSF technologies worldwide [7].

Insect farming is a new farming technology with a vast potential to boost commercialization in the livestock sector [8]. Producing insects can create new businesses and income opportunities for BSF farmers. At the same time, it provides 'protein to livestock farmers and the feed industry, reducing the dependency on imports and sustaining the environment through less extractive production methods. By increasing self-sufficiency in feed protein supply, insect farming might even mitigate effects of future crisis. During the COVID 19 pandemic, when people and goods movement was restricted, Kenyan farmers' access to *Omena* supplies from Western Kenya and feed protein supply from international markets was impaired.

BSF is a resistant insect species that can survive and multiply in various environmental conditions including oxygen-deficient conditions, under drought, and sometimes under inadequate food supply [13]. They reproduce and grow fast, illustrating a very high conversion efficiency. They represent no threat to human or animal health because BSF adults do not feed, and neither do they carry any transmittable disease vectors. Sizable benefits have been attributed to the use of insects in animal feed [4,9,10] amongst them is the capacity to facilitate waste disposal which has proven to be difficult and cost-intensive if carried out correctly, especially in urban areas. The use of waste as a substrate for insect production can help solve these challenges. Approximately seven kilograms of feed biomass (substrate) can produce one kilogram of BSF biomass [14], and another 5 to 6 kg of frass which can be used as a raw material for organic fertilizer production, thus showing the feeding effectiveness and the potential for cyclic production of the insects.

BSF farming can provide additional income to the producers and offer a symbiotic relationship between agriculture and insect rearing [15]. Insects are reared on smaller surfaces than other possible protein sources, resulting in higher protein yield per production area than most livestock or protein crops, including soybean. By replacing fishmeal from wild catches, BSF protein can reduce overfishing and the unsustainable use of marine resources. In addition, insects have a high conversion efficiency of feed to biomass with lower greenhouse gas emissions per kilogram of meat than pigs and cattle [16].

Before releasing innovations, it is vital to understand the context and demands of the target groups to ensure a positive response to the technology. As a result, the Insect for Feed project (INSFEED), which is promoted by the International Centre of Insect Physiology and Ecology (*icipe*), has supported initiatives to raise farmer awareness. Lack of awareness is a barrier for uptake of the technology and an investment in BSF production. Although BSF farming is becoming a rapidly expanding agribusiness, it still has received insufficient publicity. Therefore, determining farmers' awareness of insect-based feeds (IBF) is a critical first step to understand possible constraints for the use of BSF as protein source and the possible investments in this new technology. Understanding farmers awareness will help to design successful dissemination campaigns and eventually support efforts to improve the supply of animal feed.

This research aims to examine poultry and pig farmers' awareness of BSF farming for feed and frass fertilizer (F.F.) production and provide gender-disaggregated evidence of the critical socio-economic factors influencing awareness. Awareness of technology such as BSF production is a prerequisite for eventual adoption. Insect farming can create income when products are sold on the market but may also be directly used as a source of protein to supplement animal feed protein for pig and poultry farmers. To further raise awareness about insect farming for feed, it is critical to understand the factors influencing farmers' awareness.

A logistic regression was used to determine the main correlates of male and female awareness. The results show that 42% male and 47% female respondents were aware of BSF farming. We find, years of education, the number of chickens owned, and membership in agricultural groups to be the main factors influencing awareness. As expected, study findings reveal that agricultural groups were key in creating awareness about new agricultural technologies.

The remainder of the paper is organized as follows. Section 2 presents the materials and data collection and analysis methods. The empirical results and their discussions are presented in Section 3. Finally, Section 4 concludes the analysis by summarising the findings and by providing policy recommendations.

2. Materials and Methods

2.1. Study Area

The study was conducted in Kiambu County (Figure 1). The county was selected because it is a peri-urban area and the *icipe* led INSFEED project county. Similarly, the study area was relevant due to the many livestock farmers in the region. The county lies between latitudes 00°25′ and 10°20′ south of the equator and longitude 360°31′ and 370°15′ east and has a tropical climate attenuated by the high altitude of over 1700 m asl. This geographical setup of high altitude provides a cycle of warm and cold climate, which provides a conducive environment for BSF breeding.

2.2. Data Collection

A mixed-method approach was used to collect quantitative and qualitative data. Data were collected using an explanatory sequential design involving quantitative data collection in the initial phase, followed by collection of qualitative data through phone interviews based on a checklist in the second phase. Data collected in the first phase (baseline survey) were analysed using a logit regression model to explain variables that describe awareness, thus showing causal relationships that could exist. Qualitative data collected in the second phase were used to verify findings from the regression analysis and collect additional information. Respondents were selected and classified as aware or not from the baseline datasets for the phone interviews. The additional interviews offered deeper meaning, rigour, and multiple perspectives to the quantitative data.

Mixed methods were chosen mainly for three primary purposes: facilitating complementarity, triangulation, and to expand and strengthen our conclusions [1]. Regarding triangulation, collation and convergence of qualitative and quantitative data were carried out to enhance credibility. At the same time, complementarity was achieved by giving more profound meaning and explanation to the causal relationships established in the quantitative analysis. The quantitative regression analysis results were used to inform the questions raised in the qualitative interviews. The use of mixed methods helped us enrich the data pool and find explanations for relations discovered through the regression analysis.

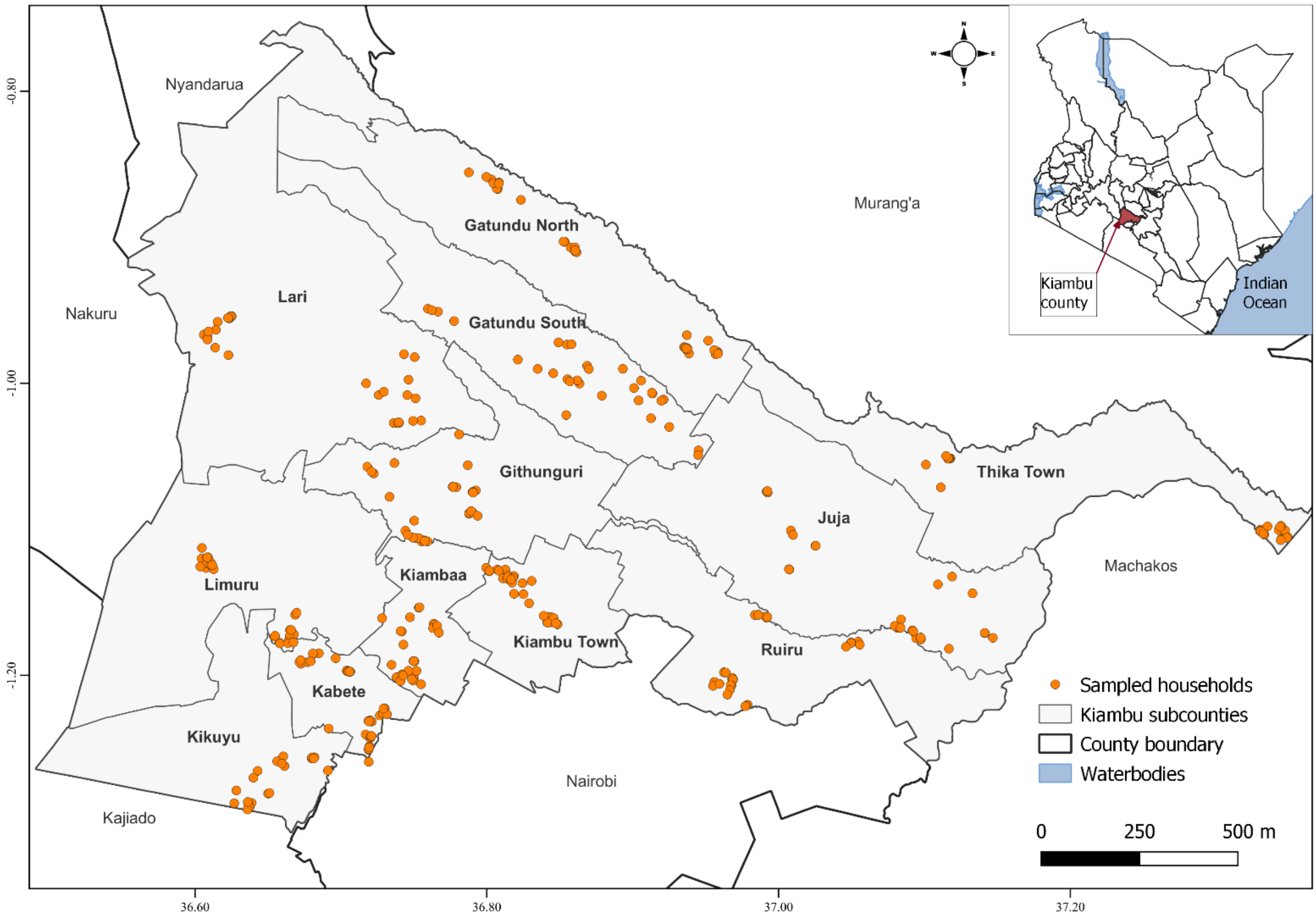

Figure 1. Map of the study area. Source: World resource center 2022.

2.2.1. Sampling Procedure

A multistage sampling technique was employed in selecting respondents. In the first stage, Kiambu County was purposively selected because it was the project area. In the second stage, all the 12 sub-counties were considered for the survey to provide good coverage of the county's geographical area and account for socio-economic, cultural, and agroecological differences. In the third stage, within the 12 sub-counties, two wards were selected based on geographic coverage and their access by road to facilitate data collection to save on time and cost. Extension agents from the Ministry of Agriculture, Livestock, and Fisheries provided a list of poultry and pig farms in the county. The list provided was thereafter put on an excel sheet. Each farming household was allocated a random number giving them an equal chance of becoming selected, and 15 farming households were chosen from each ward. In total, 370 farming households, including 10 households as a cushion for non-response rate, were randomly selected. In the 370 households, a household questionnaire was administered in addition to an individual questionnaire (targeting both genders) that covered 455 individual respondents, of which 223 were men and 232 women. 110 households had dual respondents, meaning both men and women from the same household were interviewed. These households were excluded from this analysis as they share farm characteristics. During data cleaning 25 households were dropped for incomplete and inconsistent responses. Therefore, a total of 235 individual questionnaires including 113 male and 122 female were used in the analysis to determine the characteristics that influence awareness across gender. After the quantitative analysis, 24 in-depth phone interviews were carried out, involving one male and one female respondent across the 12 sub-counties of Kiambu.

2.2.2. Analytical Framework or Model Specification

Logistic regression was used to analyse factors influencing farmer awareness of insect farming among poultry and pig farmers. The logit model was preferred to linear regression models such as Ordinary Least Squares and Linear Probability models because it best fits when the dependent variable is dichotomous. The dichotomous dependent variable violates the linearity assumption in an ordinary regression. The logit model copes with the problem by transforming the dependent variable into logs, allowing linear modelling of a non-linear dependence. The logit model is preferred to the probit model because it relies on log-odds, which can be transformed into odds ratio, making it easier for interpretation. Thus, according to Greene [17], the functional form of the logit model was specified as follows:

$$P = (Y = 1) = \frac{e^{\beta X_i}}{1 + e^{\beta X_i}} \tag{1}$$

with the cumulative distribution function as follows;

$$F(\beta x) = \frac{1}{1 + e^{\beta X_i}} \tag{2}$$

where Y is 1 if the farmer is aware of insect farming and 0 if otherwise.), X_i is a vector of independent variables and β_S are the slope parameters associated with independent variables. Equation (2) can also be written as:

$$P_i = \frac{1}{1 + e^{-Zi}} \tag{3}$$

The probability that a farmer is not aware of insect farming can be expressed as in Equation (4), while the probability that a farmer is aware of insect farming is given by Equation (5):

$$1 - P_i = \frac{1}{1 + e^{Zi}} \tag{4}$$

Therefore, Equation (4) can be expressed as:

$$\frac{P_i}{1 - P_i} = \frac{1 + e^{Zi}}{1 + e^{-Zi}} \tag{5}$$

where $\frac{P_i}{1-P_i}$ is the odds ratio in favour of farmers' awareness about insect farming. The odds ratio is the ratio of the probability of farmers' awareness of the probability of not being aware of insect farming. Finally, by taking the natural logarithms of Equation (5) then, it is expressed as in Equation (6):

$$L_i = ln\left[\frac{P_i}{1 - P_i}\right] = Z_i = \beta_0 + \beta_1 X_1 + \ldots \beta_n X_n \tag{6}$$

where P_i indicates the probability of farmers' awareness ranges between 0 and 1, and Z_i is a function of n predictor variables (X_i). the probability for farmers' awareness of insect farming with a value of 1 for awareness and 0 for non-awareness, β_0 is the intercept, $\beta_1 \ldots, \beta_n$ are the slope parameters in the model, and ε is the error term.

The explanatory variables used were identified through a literature review of previous empirical studies on awareness [11,12,18,19].

2.2.3. Qualitative Analysis

Detailed transcripts from the 24 in-depth phone interviews were generated from the Kiswahili recordings and translated to English. Interview notes were compiled during the interviews. Thematic codes were developed and applied to the transcripts to analyse the qualitative findings. The codes were structured to capture all the themes from the interview checklist. A three-level coding approach was used, with the first level code representing general themes while the second and third levels captured more specific themes within the general ones. For instance, the first level captured a general theme on the influence of agricultural groups on awareness creation, and the second level indicated whether the effect was positive or negative. Finally, in the third level are reasons on how agricultural groups influence awareness creation.

The themes used in the coding were standard across all the transcripts capturing the discussions that arose during the interview. Although the themes developed in the coding were in line with the interview discussions, this paper only presents reports on the themes related to the quantitative results. During data analysis, meaningful quotes from the interviews were selected to support or contradict and interpret the quantitative results. All the identified themes were collated in an Excel sheet to demonstrate theme frequencies and facilitate pattern identification in the final analysis step.

3. Results and Discussions

3.1. Awareness of Insect Farming across Gender

Fisher et al. [20] conceptualize awareness as the ability to be familiar with a practice or technology. De Groote et al. [21] defined awareness as a point where a farmer has heard about technology or product such as quality protein maize but does not necessarily understand its nutritional benefits. In this study we used De Groote's definition and consequently asked the respondents whether they had heard about insect farming or not. The same question was used in the qualitative phase. In addition, respondents were asked on the source of information about BSF farming. Therefore, we define awareness as farmers knowledge about insects for feed farming and not necessarily having complete knowledge about insect farming practices. The awareness variable here accounts only for the incidence of knowledge of the existence of the technology. This definition is consistent with other studies that look at farmers' awareness as individuals knowing about a specific technology [22–24].

The sampled population was selected with gender in mind to represent both males' and females' awareness. The study sample from Table 1 above indicates that amongst the women interviewed, about 47% were aware of insect farming compared to approximately 42% of the male respondents. However, awareness was not significantly different among the two groups (χ^2 ratio Table 1) [25]. Qualitative results showed that men were involved more in other non-agricultural economic activities and thus predisposing more women to agriculture and in extension to awareness of new agricultural technologies. The proximity of the sampled area to the country's capital city has contributed as a push factor for male household heads in participating in non-farm employment (67%) and, therefore, reduced interest and participation in agricultural innovations such as BSF farming.

Table 1. Awareness of insect farming among male and female respondents.

		Overall	Male	Female	χ^2 Ratio
Awareness	Aware (%)	44.26	41.59	46.72	0.302
	Not aware (%)	55.74	58.41	53.28	

Note: χ^2 ratio indicates difference between male vs. female.

In contrast with other studies [26,27] where men are found to be more aware of agricultural technologies than women. This study findings show that women were equally aware of BSF farming as their male counterparts. Women, particularly female household heads, seem to be more interested in additional income-generating activities such as insect farming. The findings were corroborated in the in-depth phone interviews, as women reported learning numerous technologies, including BSF farming, from neighbours and informal women organizations to which they belong. In addition, the age differences between the male and female respondents could significantly explain why women were equally aware of BSF farming as their male counterparts—female respondents were averagely younger

(48 years) than male respondents (55 years). Similar to Ali et al. [28] findings, younger farmers are more likely to be innovative and keen to try new technologies and methods to improve agriculture than their older counterparts, who are not aware of recent agricultural innovations or are reluctant to learn and try new approaches.

From the number of animals that the respondents owned, it was evident that most female respondents owned fewer animals (both pigs and poultry—Table 2) than the male respondents. The more animals a farmer has, the less they are inclined to seek innovative farming methods such as BSF farming as they risk innovation failure. These results align with Chia et al. [29], who found that the number of animals (poultry and pigs) determines the likelihood of the new technology failing to operate as intended.

Table 2. Description and measurement of variables in the logistic regression model.

Variable	Definition of Variables and Measurement	Mean			Significance
	Continuous Variables	**Overall (235)**	**Male (113)**	**Female (122)**	**t Value**
Age	Age of a farmer in years	51.2995	55.11	47.77	−6.0979 ***
Education	Number of years of schooling of the farmer	7.5473	7.7801	7.3318	1.1672
Depn–ratio	Proportion of people < 15 years and >64 years to 15–64 year old	0.2116	0.4019	0.0354	−24.3045 ***
Pigs	Number of pigs owned	5.9346	9.4798	2.6509	−12.7474 ***
Chicken	Number of chickens owned (Summation of layers, broilers, and free-range)	134.4258	136.98	132.06	−0.3403
Farm size	Number of acres of land currently owned	1.8367	1.9310	1.7495	−0.5692
	Categorical variables		Percentage		χ^2 ratio
Occupation	% of respondents with farming as main job occupation	75.74	77.88	73.77	−0.6549
Agric–group	% of respondents participating in agricultural groups	45.11	76.99	15.57	−19.3235 ***
Extension	% of respondents with confidence in extension skills/knowledge received	51.06	87.61	17.39	−25.2224 ***

Note: *** $p < 0.01$, t-value and χ^2 ratio indicates difference between male vs. female.

3.2. Descriptive Results

The ages of the farmers appeared to be unevenly distributed across the male and female respondents, as indicated by the t-test. Most of the sampled farmers fell within the middle age category of between 40 and 55 years. The mean age for men was 55 years, while that of female respondents was 48 years. Individuals in peri-urban areas such as Kiambu aged 22 to 60 years are considered candidates for formal employment. They tend to engage in formal employment sectors as their priority. However, the qualitative survey sampled individuals indicated that a constrain in the formal employment sector was a push factor towards farming. Furthermore, they indicated that agriculture as a business is becoming more lucrative compared to some formal employment. While working with small-scale farmers on the adoption of environmentally friendly agricultural technologies, [30] found out that there is a positive relationship between age and exposure to new farm ventures.

The age of the respondent predisposes a farmer to better farming techniques through "learning by doing" and better management skills. Age is assumed to increase the probability of awareness and adoption but at a decreasing rate as the age increases [26]. On the other hand, we assume that younger farmers have a high propensity toward emerging technologies in farming than relatively elderly farmers and are more willing to take the risk to try new technologies, *ceteris paribus*. The study hypothesized that as age increases, technology awareness increases, but the marginal propensity to adoption decreases as elderly farmers tend to be risk-averse and vice versa—the younger the farmer, the higher the urge to learn. However, the farmer's age up to a certain level increases their probability of awareness, albeit at a diminishing rate, as indicated by the female respondents in Table 3.

Table 3. Logistic regression results on factors influencing farmer awareness about insect farming.

	Male Respondents			Female Respondents		
Variables	**Coef.**	**dy/dx**	**Std. Err.**	**Coef.**	**dy/dx**	**Std. Err.**
Age	0.0075	0.0001	0.0879	−0.3411	−0.0017 *	0.1931
Education	1.8142	0.0175 ***	0.5664	1.7617	0.0088 **	0.6942
Depn–ratio	−9.5057	−0.0915	20.5352	2.2715	0.0113	7.1413
N–pigs	0.0871	0.0008	0.8824	−0.6631	−0.0033 **	0.2783
N–chicken	0.2261	0.0022 **	0.0881	0.6553	0.0033 ***	0.2170
Farm size	0.0128	0.0001	0.1326	0.2220	0.0011	0.2129
Agric–group	−3.3855	−0.0326 *	1.8547	−12.2684	−0.0610 **	5.0571
Occupation	−0.0715	−0.0007	0.4496	−0.1988	−0.0010	0.4252
Extension	−0.0806	−0.0008	1.8784	−0.1204	−0.0006	2.2202
–cons	−21.8656		11.1136	−31.4951		9.4541
	Male			Female		
	Wald χ (8) = 39.66			Wald χ (8) = 17.30		
	Prob. > χ^2 = 0.0000			Prob. > χ^2 = 0.0271		
	Pseudo R^2 = 0.9523			Pseudo R^2 = 0.9738		
	Log pseudo likelihood = −7.083784			Log pseudo likelihood = −4.150405		

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

There was a significant difference in pig ownership between male and female respondents. The mean number of pigs among the male was nine pigs, while that of their female counterparts was approximately three pigs. The most plausible reason for the difference in the number of pigs owned by men or women is attributed to the fact that pig rearing needs a higher initial investment and a regular supply of feed as they are heavy consumers. In addition, pigs require labour-intensive routine management practices, which is less attractive for women. Therefore, investment cost and labour input are a deterrent to female farmers whose access to resources is lower, and their marginal propensity towards labour-intensive ventures is low compared to male farmers. This is in line with the findings by Dorh et al. [27], who concluded that men are relatively more resilient than their female counterparts. Given that pig rearing management practices are labour intensive, men are thus relatively more involved in pig production.

The dependency ratio was statistically different between the male and female respondents. There are more dependents (children below 15 years old and adults above 64 years old) compared to adults (>15 years and <64 years old) in households where we interviewed male household members compared to those households where female household members were interviewed. The implication is that the economically active population and the overall agricultural economy face a more significant burden to support and provide the agricultural output needed by children and older persons who are often agrarian dependent.

Agricultural group membership among male and female respondents was statistically different. About 77% of male respondents participated in an agricultural group, while only 10% of women respondents reported being members of an agricultural group. This implied that agricultural groups were majorly constituted and attended by a male household member. Information on new agricultural technologies is often shared through such platforms, and extension officers often use groups to share information. According to Skevas and Kalaitzandonakes [31] membership in an agricultural group was expected to positively impact the intensity of project awareness, adoption, and ultimately, profitability and quality of agricultural outputs.

On average, 88% of the male respondents reported having had contact with extension service providers, while 11% of the female respondents had contact with extension services. This significantly influences the agricultural outcome among the different gender groups. Farmers must have information about the intrinsic characteristics of the BSF before considering adopting production or not. Studies such as Ragasa et al. [32] have shown that extension agents are biased towards male farmers instead of female farmers due to their significant differences in resource ownership and adoption rate.

3.3. Determinants of Insect Farming Awareness among Pig and Poultry Farmers

Table 3 provides the estimated marginal effects from the logistic regression model analysis and standard errors and p-levels of significance for male and female respondents. The χ^2 results show that male farmers χ (8) = 39.66 and female farmers χ (8) = 17.30 were statistically significant. This meant that logistic regression model's explanatory power was significant. The Pseudo R2 in male and female respondents was 0.9523 and 0.9738, respectively, indicating that the model's independent factors adequately explained BSF farming awareness. For several independent variables, the marginal effects were significant. They were interpreted in terms of how a unit change in the explanatory variable influenced the probability of a respondent being aware.

Age of female respondents had a negative relationship with BSF awareness. This indicates that as the age of female farmers increases by a unit, the probability of insect awareness decreases. A possible explanation is that older female farmers are more risk-averse than younger females. Furthermore, another possibility is that female respondents may be economically less secure than their male counterparts and that they do not want to involve themselves in decision making. As a result, the former is less capable of seeking information on new agricultural technologies. These results align with the findings of [33] who found older females tend to refrain from farm technologies decision making, likeliness to be risk-averse and less economically secure than their male counterparts and thus less capable of having awareness seeking behaviour. Similarly, Fisher et al., [25] found that the household heads' age was negatively associated with their familiarity with some innovative conservation agriculture practices such as crop rotation and organic manure use. The qualitative findings showed that most young people tend to remain innovative and try new things to improve their productions. Still, the older farmers would stick to their old habits and what they consider proven production methods. They say that they do not have plenty of time to try out new technologies as the youthful population do.

Respondents with a high number of chickens were more likely to be aware of BSF farming. Probably farmers tend to minimize their production cost while maximizing their return on investment by supplementing their routine feeds with these insects. BSF have valuable ingredients for the formulation of chicken feeds. For example, BSF larvae have suitable crude protein content and other nutritional benefits for good pig and poultry nutrition [34]. Several studies have found a positive association between livestock number and technology awareness [25,33,34]. Fisher et al., [25] found that farmers with more extensive operations will be more willing to invest in new technologies. Meinzen-Dick et al. [35] also found a positive relationship between number of animals and awareness of new technologies. From the qualitative results, most farmers suggested that it was local knowledge that chickens feed on insects, including BSF, and some, in their local capacity, seek to rear them in their compost pits and later feed them to the chicken.

The number of pigs owned by respondents had a significant negative relation with insect farming awareness among female farmers. Female farmers are likely to be busier than male farmers, and they handle multiple household chores and farming activities. Thus, female farmers with more pigs are likely to be busier and thus likely to have reduced awareness of emerging technologies such as BSF farming. The results corroborate Subramaniam and Islam [35] findings that showed that women entrepreneurs are significantly involved in their farms' day-to-day operations in Singapore. For the success of their farm and the well-being of their employees, married women entrepreneurs must balance many roles: wife, mother, and business owner. As a result, many female entrepreneurs suffer work-family conflict since they must balance work and family obligations.

Education level and insect farming awareness positively correlated both in male and female respondents. A high level of formal education would mean that most farmers are expected to be cognizant of a new technology within a relatively shorter period. Sennuga et al., [36] suggested an essential link between education level, personal empowerment to escape poverty, possession of appropriate information, and making informed choices. Farmers with higher levels of education tend to be more efficient in production. Better performance by more educated farmers may be attributed to the fact that education gives the farmers the ability to perceive, interpret and respond to new information and improved technology such as fertilizers, pesticides, and planting materials much faster than their counterparts [37,38]. In addition, Alatinga and Williams [28] indicate that more educated individuals can quickly and effectively process information about new technologies. On the other hand, individuals with low levels of education could find it hard to interpret information on new technologies and are also reluctant to participate in awareness programs. Materu et al. [29] reinforce this for Tanzania, where they found that educated farmers were more innovative and embraced new technologies and their adoption, increasing their awareness. Similar to the quantitative results, qualitative findings find a positive association between having a high level of education and being aware of insect farming. Phone interview participants remarked that individuals with secondary education and above are considered to have more knowledge of new technologies, positive attitudes towards new agricultural technologies, and make critical decisions easier. Furthermore, they are more open to learning new things and have access to multiple information sources such as the use of the internet.

Beatrice, a 50-year-old poultry farmer, remarked, "Educated people have a wider platform to acquire information. Most have access to the newspaper, social media, and the entire internet. My neighbour's son learned how to keep broiler chicken from YouTube. Educated people also easily understand and process information than their uneducated counterparts" (In-depth phone interview participant, 8 July 2020)

Finally, membership in an agricultural group (dummy variable) indicates that those farmers who had membership in this group were less likely to be aware of BSF farming than the comparison group of non-members. While this negates the axioms of social capital and other literature about the importance of group membership, a key explanation was captured during in-depth phone interviews. Many farmers noted that they received information on BSF farming through friends in their informal networks and not through the official channels of extension workers and agricultural groups. Moses Thiga, a 53-year-old poultry farmer, remarked, "*Men have many social and work-related activities from which they learn about new technologies.*" (In-depth phone interview participant, 8 July 2020).

For women farmers, informal women groups were the primary source of information, as very few were registered members of agricultural groups. In the phone interviews, women confirmed this finding and stated women groups were the most influential group through which they received agricultural information. One of the interviewees, Eunice Nyokabi, a 60-year-old poultry farmer, noted, "*Very few women are in agricultural groups; instead, we have our own women groups within which we learn a variety of things as they discuss a wide range of topics ranging from economic, social, financial, and agricultural information.*" (In-depth phone interview participant, 7 July 2020).

Although men are the main owners of resources and farm assets and are dominantly registered as members of the agricultural groups, thus exclusive men group membership is not a sufficient factor for them to receive information about innovative technologies such as BSF production. Phone interviews could not conclude this discrepancy because when asked to name the most influential groups in their areas, most interviewed farmers mentioned agricultural groups. They were considered an avenue through which they learned new agricultural information.

The qualitative interviews also revealed that farmer groups, in contrast to women's groups, are often targeted by agricultural extensionists from government, non-governmental institutions, universities, and research institutions, exposing them to new technologies. Paul Gitau, a 62-year-old poultry farmer, remarked: *'most organizations, when designing agricultural programmes, usually target agricultural groups or ask the locals to come up with agricultural groups with which they work. This has always been the norm and has worked well so far.'* (In-depth phone interview participant, 9 July 2020). In our interviews, agriculture and women's groups were mentioned to provide opportunities to receive agricultural information for male and female farmers, respectively. Nevertheless, farmer to farmer learning seems essential to acquire information about new agricultural innovations that are not part of the standard training curricula of extension agents.

According to Mudege et al. [39], extension agents assume that men are family heads, hence the primary decision-makers and the owners and controllers of agricultural resources. Extension agents believe that information provided to household heads trickles across to other household members, which is not the case [39]. Similarly, Ragasa et al. [32] found that most extension service providers persist that women are not farmers, notwithstanding their vast contributions to agriculture. They don't address women as necessary partners for training and information sharing.

4. Conclusions and Policy Implication

In determining smallholder pig and poultry farmers' awareness on BSF farming, the results revealed that less than half of pig and poultry farmers in Kiambu County are aware of the potential use of insects as feed. The main determinants of farmers' awareness were farmers' years of education and membership in agricultural groups. There were significant differences on determinants of farmer awareness across gender. There was concurrence from qualitative and quantitative findings on the importance of group membership. For the qualitative interviews, most of the respondents mentioned that women groups are the most influential in creating technological awareness amongst women. However, women groups have little access to formal extension services, and awareness about important agricultural innovations. Innovations such as BSF production are often not disseminated through these groups. The findings of this study will benefit the design of well-targeted awareness creation activities. However, these findings are context-specific and might not be applicable in locations that do not enjoy the semi-urban setting of Kiambu county and to areas with different cultural backgrounds. Future studies should explore coverage of more counties to improve the application study findings. Other than gender, a study targeting factors influencing youth awareness could also contribute to increasing youth participation in BSF farming.

The study recommends that policy interventions by county governments in Kenya should be geared towards increasing farmers' technical knowledge through investing and building the capacity of farmer groups. There should be more emphasis to include women's groups in formal agricultural extension. Similarly, farmers with low education levels or years of schooling should be targeted to increase awareness using approaches they can relate to. To enhance farmers' awareness, efforts should be geared towards sensitizing extension service providers on innovative technologies such as BSF farming. Including women's groups in extension activities would increase information flow and create awareness pathways among wives, independent from their husbands' training. Qualitative interviews established a general need for more agricultural training while considering specific requirements of male and female farmers. The involvement of local lead farmers (male and female) that are trusted by farming households will improve farmers willingness to adopt new technologies. Efforts should also be made to increase farmers' participation in group activities and ensure that they are actively involved in discussions on agricultural technologies and their adoption. The introduction of farmer to farmer learning approaches, utilizing men and women farmer groups or neighbour initiatives as target entities, will further raise awareness and demand for IBF. Training materials need to be adapted to the requirements of these approaches. Producing materials which can be easily shared between those groups will support awareness raising efforts, create demand for insect protein and encourage farmer to invest in BSF production.

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Informed Consent Statement: Informed consent was obtained from all the respondents in the study.

Data Availability Statement: The data presented is available on request from the corresponding author.

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