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Potential Use of Insects as Raw Material in Food for Feed to Alleviate Some Chicken Production Constraints in Adamawa Region, Northern Cameroon

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Abstract

Chicken production in Cameroon is steadily increasing, even in regions traditionally dominated by cattle and goat farming. A significant constraint to this growth is the high cost and limited availability of feed, which represents the largest portion of overall production costs. To enhance the sector's contribution to population well-being, sustainable feed alternatives are essential. Black soldier fly larvae (BSFL, *Hermetia illucens*) present a promising solution by converting organic waste into nutrient-rich biomass, offering a sustainable method for waste management and producing high-quality proteins, lipids and micronutrients to help mitigate supply shortages of premix (vitamin concentrates) essential for feed formulation. To explore stakeholder acceptance of insect-based feed, a study was conducted in the Vina Division of the Adamawa region in Cameroon, from July to August 2023, involving 107 participants. The survey examined socioeconomic profiles of poultry farmers and poultry feed sellers, and afterwards focused on the acceptance of the use of BSFL as ingredient in poultry feed. Results indicated that poultry farmers were predominantly male, aged between 30 and 40 years. Most poultry farmers had attained a secondary education, while the majority of poultry feed sellers had only completed primary education and lacked formal qualifications in chicken breeding. Consequently, their skills are poor, less than five years of experience. The most important constraints identified were high costs of ingredients needed in the formulation of feed, product marketing difficulties and, disease management. Traditional protein sources like soybean, fishmeal, and groundnut cake were commonly used, but there was notable openness to insect-based feed. Around 76% of poultry farmers and 100% of poultry feed sellers were willing to use BSFL if they were cost-effective and beneficial for poultry health. The acceptance of insect meal indicates a promising future for its use in poultry feed formulations, pending further studies to confirm its efficacy and economic viability.

Keywords: black soldier fly, feed formulations, entomophagy, Cameroon

1. Introduction

Chicken is one of the main types of animals used in industrial animal production, and its breeding has rapidly developed worldwide over the past decades (Goran et al., 2023; Sumbule et al., 2021). It provides a stable supply of proteins and ensures food and nutritional security for most of the population in rural areas globally, particularly in developing countries (Vaarst et al., 2015). The industrial production of chickens, turkeys, ducks, and geese represents the vast majority (up to 98% for meat and 92% for eggs) of global poultry production (Mottet & Tempio, 2017). The global poultry production was estimated at 137.8 million tons in 2021 by the Food and Agriculture Organization of the United Nations (FAO, 2022), with the largest producers being the United States of America (USA) (22.705 million), China (19.500 million), Brazil (14.076 million) and the European Union (EU) (13.769 million) in 2020 (Association of Poultry Processors and Poultry Trade in the EU countries [AVEC], 2021; Goran et al., 2023). Globally, poultry production has experienced steady growth over the previous decade, with a 1.32% increase in 2021 (FAO, 2022). This increase in production has encouraged

unsustainable practices for animal feed production, such as overexploitation of wild fish and soybean monocultures leading to widespread deforestation in the Amazon to meet the nutritional needs of a continuously growing global population (FAO, 2020).

The latest United Nations (UN) projections estimate that the world population is expected to reach about 9.7 billion by 2050, with Sub-Saharan African countries contributing to more than half of this increase (UN, 2022). Cameroon is projected to experience substantial population growth as part of this trend, with estimates indicating a rise to over 32.9 million by 2030 and approximately 49.8 million by 2050 (UN, 2017; World Bank, 2016). The increase in the global population necessitates an increase in global food production (Lopes et al., 2022). To meet the growing demand for meat, it is essential to promote sustainable food production by exploring alternatives to animal feed (Davis & White, 2020; Siddiqui et al., 2024).

In Cameroon, the poultry sub-sector represents around 55% of the livestock sector and contributes 30% to the agricultural sector, with a 42% market share of national meat production covering 14% of animal protein needs (GIZ, 2018; Polepole et al., 2019). It is therefore an important element of rural households' livelihoods as a source of food, employment, and income for the population (Dzepe et al., 2019; Okello et al., 2021). However, poultry farming in the country remains dominated by the traditional sector, which accounts for more than 60% of the production across the national territory (Ministry of Livestock, Fisheries and Animal Industries (by the French acronym, MINEPIA, 2011). According to the statistical yearbook of the livestock, fisheries, and animal industries sub-sector (by the French acronym, ASSEPIA, 2021), poultry production has increased between 2015 (80,317,865 heads) and 2019 (85,579,493 heads), then dropped in 2020 (53,630,641 heads) followed by a slight increase in 2021 (54,166,948). Despite a high production of compound feeds in 2021 for broilers and laying hens, respectively 89,831 and 269,527 tons (ASSEPIA, 2021), a lack of protein supplements results in a continued rise in their costs and significant imports (MINEPIA, 2014; Polepole et al., 2019). To achieve the import substitution objectives promoted by the Cameroonian State, it is necessary to develop local alternatives for animal feed to ensure sustainable, safe, and profitable farming (FAO, 2011, 2013).

Insects, an attractive and important natural food source for many vertebrates, appear as one of the solutions for the future (Gahukar, 2016; Megido et al., 2015; Polepole et al., 2019). In recent years, growing interest in using insects, particularly the black soldier fly (BSF, *Hermetia illucens*, Linnaeus, 1758) in animal feed formulation has been explored worldwide (Ganesan et al., 2024; Shaviklo, 2022). BSF larvae have good protein content (38.5-62.7%), a well-balanced amino acid profile, a good fat content (14-39.5%), and micronutrients such as iron and zinc (Chia et al., 2019; Lu et al., 2022; Onsongo et al., 2018). These qualities make them a promising feed supplement. BSF larvae have a remarkable ability to consume and decompose organic waste, including food scraps (Joly & Nikiema, 2019). These larvae can convert organic waste into valuable biomass, significantly reducing the volume of waste that would otherwise end up in landfills. This process not only mitigates environmental pollution but also produces a nutrient-rich byproduct that can be used as compost or fertilizer (Ganesan et al., 2024). Moreover, BSF larvae are highly nutritious feed ingredient for poultry and other livestock (Joly & Nikiema, 2019). This alternative protein source can replace conventional feed ingredients such as soybean and fish meal, which is often criticized for their environmental impact and intensive production methods (Stejskal et al., 2020; Wachira et al., 2021). Thus, the use of BSF offers a multifaceted solution to the challenges of food waste management and sustainable protein production (Okello et al., 2021). By leveraging the natural capabilities of this insect, we can create a more sustainable food system that reduces the current over-reliance on fish and soybean meals, in favor of a more resilient and resource-efficient agricultural model (Okello et al., 2021). To achieve this, gaining the support of consumers, stakeholders, and regulatory bodies is important (Ganesan et al., 2024). Additionally, the use of insects in animal feed could be subject to specific regulations and legal conditions, including considerations regarding the safety of these new animal feed ingredients is also important (Ganesan et al., 2024).

Recently, the European Union (EU), Australia, Canada, and the United States of America have allowed the production and trade of BSF larvae as animal feed according to defined criteria (Ganesan et al., 2024). Interestingly, many countries with entomophagy traditions do not have specific regulations on the use of insects as animal feed (Ganesan et al., 2024). In Cameroon, the absence of legislation on the use of insects in animal feed could be due to the fact that research and actions in the field of edible insect farming and valorization are in their early stages (Polepole et al., 2019). Studies on the acceptance of insect-based foods by consumers (Okello et al., 2021; Ribeiro et al., 2022; Sogari et al., 2022) have revealed that study participants were willing to accept the use of insects in animal feed, particularly for fish and poultry (Ganesan et al., 2024; Lu et al., 2022). However, to our knowledge, no study has assessed the opinion of Cameroonian poultry stakeholders on the use of BSF larvae in poultry feed. Therefore, this study aims to assess the acceptance of incorporating BSF larvae

into poultry feed and to identify the factors that influence the opinions of stakeholders (poultry farmers and poultry feed sellers) in the Vina department, Adamawa region of Cameroon.

2. Methods

2.1 Sampling Sites

During July and August 2023, surveys were conducted among poultry farmers and poultry feed sellers in the Vina Division of the Adamawa Region of Cameroon. This location was chosen because chicken production is steadily increasing in the area, which has traditionally been dominated by cattle and goat farming. Additionally, the university where the experiment on BSFL was carried out is located in this region. The timing of the survey was selected as it marks the beginning of the poultry farming season in preparation of the end-of-year celebrations, during which demand for chicken is high on the market. Thus, increasing the likelihood of encountering a large number of active poultry farmers. The snowball sampling method was employed, whereby initial respondents assisted in identifying additional poultry farmers within the locality (Salganik & Heckathorn, 2004). This method was selected due to the absence of a comprehensive registry from the regional office of the Ministry of Livestock, Fisheries, and Animal Industries. According to local ministry officials, not all stakeholders formally register their activities, making it difficult to obtain a complete sampling frame. Consequently, snowball sampling was deemed the most appropriate approach to maximize outreach and ensure broader representation among active poultry farmers. All animal feed sellers are located along the same commercial avenue in the main market of Ngaoundere. Therefore, to identify the initial participants, we went directly to this market area where feed sellers are concentrated. Through conversations with individuals present at these sales points, we were able to meet our first poultry farmers, who were there to purchase feed for their animals. These initial farmers then helped us identify additional participants, as they are generally familiar with one another within the local poultry farming community. The surveys being conducted across three subdivisions of the town (Ngaoundere I, Ngaoundere II and Ngaoundere III), a sample of 25 poultry farmers was set for each subdivision. This number was determined based on the growing importance of poultry farming in the region and the lack of official data, making it necessary to set a fixed target per subdivision. For poultry feed sellers, a total of 25 respondents were determined for the entire Vina Division, as most sales points are concentrated in a single area specifically, the small market of Ngaoundere. This brought the total sample size to 100 individuals interviewed.

Table 1. Sites surveyed in the three subdivisions

Subdivisions	Sites
Ngaoundere I	Bideng, Burkina, Bamyanga, Beka, Onaref, Haut-plateaux
Ngaoundere II	Baladji II, Joli soir, Aéroport, Polyvalent, Nord-cifan, grand-marché
Ngaoundere III	Bini, Dang, Malang, Manwi, Gadabidou, Hourouchoua, Bidjara

2.2 Evaluation of the Acceptability of Insect-Based Feed for Poultry Farmers and Poultry Feed Sellers

Our survey sheet included a section assessing perception of poultry farmers and poultry feed sellers regarding insect-based feeds for poultry. In line with the study by Okello et al. (2021) in Kenya on farmers' perceptions of commercial insect feeds, respondents were given a brief description of our research on black soldier flies prior to the interviews. The information provided included an illustrated description of the insect, detailing its life cycle, biological characteristics, and harvesting process, as well as the potential for its inclusion in feed formulation and the associated by-products generated. Based on four defined criteria (age, gender, level of education and length of time in activity), the acceptance of products based on black soldier fly larvae was assessed among poultry farmers and poultry feed sellers. The respondents were asked whether yes (1) or no (0) they would accept insect-based meal as a source of protein to replace conventional protein either in animal feed, in case of a poultry farmer, or for marketing, in case of a poultry feed seller.

2.3 Data Collection

Information was collected by means of interviews following a well-structured questionnaire and direct observations on the field. The questions were of a socio-professional nature, with specifics depending on whether the respondent was a poultry farmer or a poultry feed seller (Appendix A). A total of 107 individuals were interviewed, comprising 82 poultry farmers and 25 poultry feed sellers. The number of poultry farmers exceeded the initial plan due to 32 respondents being surveyed in the Ngaoundere II subdivision, rather than the

intended 25. Discussions with poultry farmers focused on how long they had been in the activity, the type of poultry raised, the size of the flock, the composition and quantity of feed used, the sources of protein used in the feed, and their current market cost. Poultry feed sellers were surveyed regarding the duration of their involvement in the activity, their feed production capacity, and the current market prices of their products. Additionally, in order to assess the extent of input scarcity on the market, all stakeholders were also asked about the challenges they face in their respective activities. With the informed consent of the participants, photographs were taken of various aspects of their facilities, including feed stocks, layout of the premises, products used, and animals housed in the pens. Prior to data collection, each participant was informed about the purpose of the study and the voluntary nature of their participation. Verbal consent was obtained before taking any photographs, and care was taken to avoid capturing identifying features such as faces, names, or specific location markers to ensure anonymity and protect participant confidentiality. All relevant information was systematically recorded on individual data collection sheets. After field collection, the data were manually entered into Microsoft Excel, where each variable was clearly labeled and coded for consistency (acceptance levels were coded as 0 = No and 1 = Yes). The cleaned and coded dataset was then imported into R for statistical analysis, where descriptive statistics and visualizations were generated to interpret the findings. Furthermore, a Multiple Correspondence Analysis (MCA) was performed using RStudio to examine correlations among variables, with the objective of determining whether acceptance of insect-based meal varied by stakeholder type (poultry feed sellers or poultry farmers), age group, or educational level.

3. Results

3.1 Socio-economic Characteristics of Poultry Farmers and Poultry Feed Sellers

The majority of the respondents were men: 93.2% of poultry farmers and 96% of poultry feed sellers (Table 2). All the poultry farmers were educated, with 29.2% having a university education level, half having a secondary education level (51.2%) and primary education level accounted for 19.5% of respondents (Table 2). The average age of the poultry farmers was between 20 and 40 years (68.2%) and the majority (64.6%) had been in the activity for less than five years. 23.1% had been in the activity for between 5 and 10 years and only 12.2% had been in the activity for more than 10 years (Table 2). Most of them (84.1%) did not receive any qualifications (training) in poultry farming and only 15.8% had received training either as livestock technicians (9.7% of the total) or as veterinary doctors (6.1%) (Table 2).

Most of poultry feed sellers were aged between 30 and 40 years old (56%). As well as poultry farmers, poultry feed sellers were all people who had received some schooling, with 72% having at least secondary education and 28% having primary education. None of them had any poultry farming training. 88% had been selling feed for less than 10 years, while 12% had been doing so for more than 10 years (Table 2). Overall, most of the participants (63.4%) were aged between 30 and 40 (Table 2).

Table 2. Survey results summary. Showing the gender distribution, age groups, and education levels of the surveyed participants, indicating a higher prevalence of men and highlighting the educational background of poultry farmers and poultry feed sellers

Parameters	Categories	Poultry farmers (n = 82)		Poultry feed sellers (n = 25)	
		Count	Percent	Count	Percent
Sex	Male	77	93.90%	24	96.00%
	Female	5	6.10%	1	4.00%
Age	20-30 years	15	18.29%	3	12.00%
	30-40 years	41	50.00%	14	56.00%
	40-50 years	24	29.27%	7	28.00%
	Over 50 years	2	2.44%	1	4.00%
Education Level	Primary	16	19.51%	7	72.00%
	Secondary	42	51.22%	18	28.00%
	University	24	29.27%	0	0.00%
Poultry Qualification	No	69	84.15%	24	100.00%
	Yes	13	15.85%	0	0.00%
Experience	Less than 5 years	53	64.63%	11	44.00%
	5-10 years	19	23.17%	11	44.00%
	More than 10 years	10	12.20%	3	12.00%

3.2 Poultry Diversity and Distribution in the Region

The town hosts a diverse range of poultry species, with broilers representing the largest group at 73.17%. This was followed by local chickens (14.6%), and laying hens (7.3%). Other species, including ducks, geese, turkeys, and quails, each accounted for less than 2% of the total poultry population were also found (Figure 1).

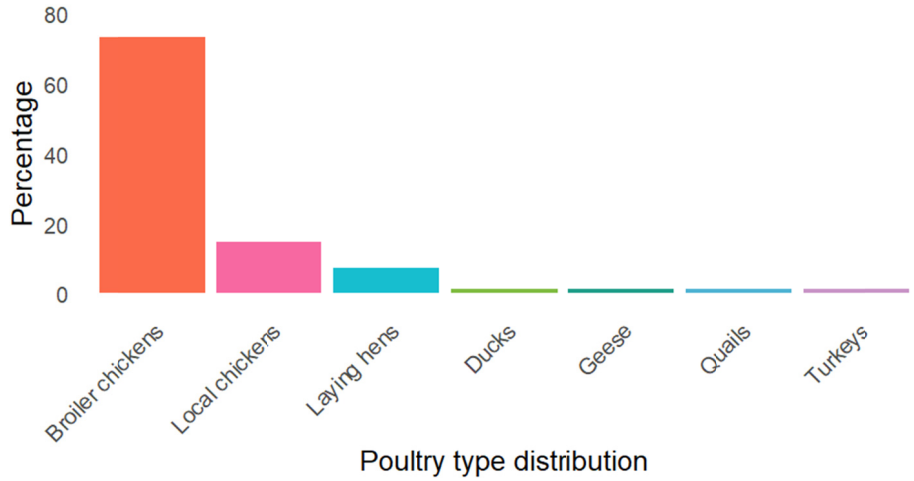

Figure 1. Distribution of different types of poultry raised in Vina division, Adamaoua Region

Broilers and laying hens were reared in a semi-intensive system (Figures 2A and 2B) because the production objectives are generally to supply the surrounding markets with chickens and eggs. However, some people raise them in small quantities for their own consumption or for additional household income. Chickens are usually sold after 45 days when they reach at least 2 kg live weight, but can be kept for up to 60 days during periods of low demand and production difficulties. Local chickens, also known as village chickens, are mainly reared under extensive systems. These chickens play an important role in meeting animal protein requirements and hold an important place in the socio-cultural life of the local communities. These birds are typically kept in free-range or semi-free-range systems, often spending the night in shelters made from locally available materials or, in the absence of such shelters, roosting in trees (Figure 2C).

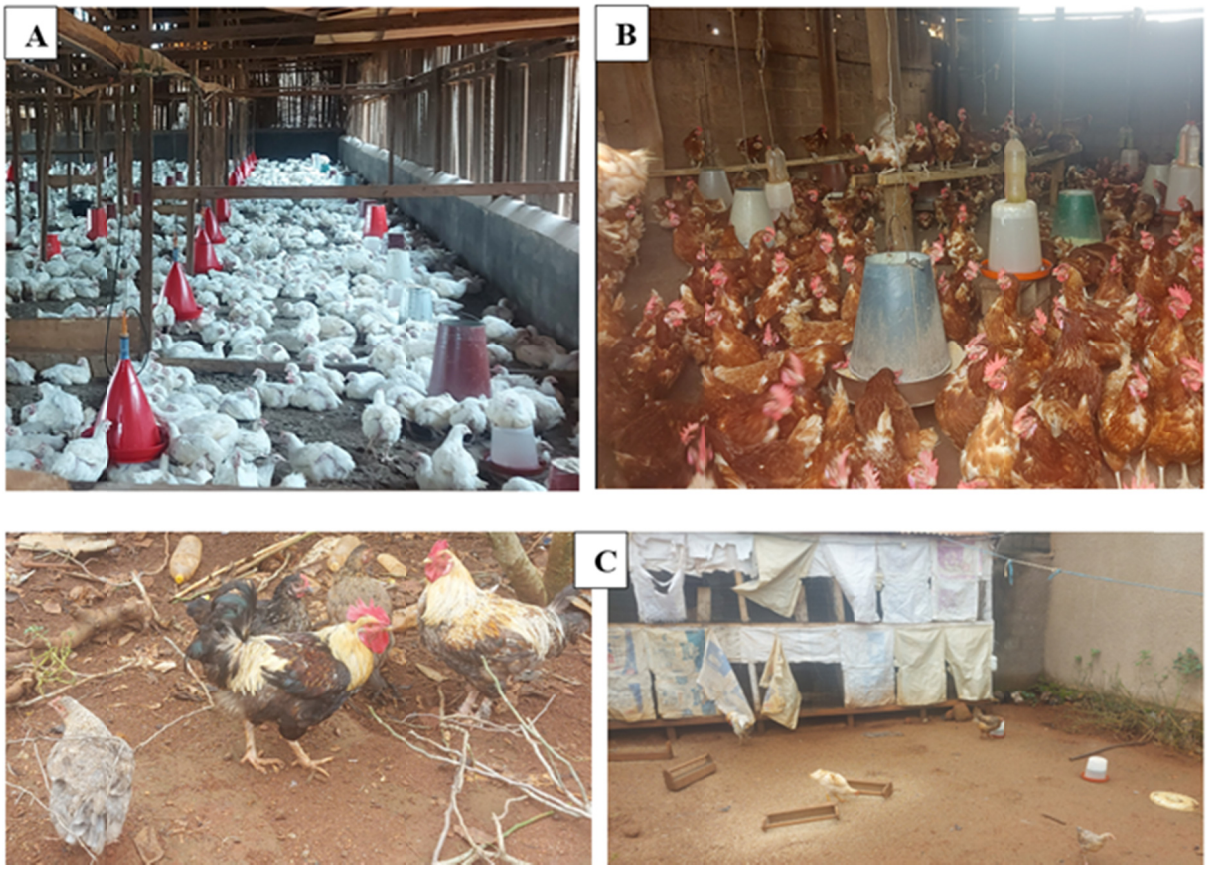

Figure 2. Types of chicken breeding facilities in Ngaoundere. A: Semi-intensive broiler farms; B: Semi-intensive layer farms and C: Extensive local chicken farms

3.3 Livestock Size and Quantities of Feed Used

Flock sizes varied among the 82 surveyed poultry farmers based on their financial capacity. Most raised broilers, with flock sizes ranging from 10 to 1,000 birds, while those rearing layers had flocks of 500 to 5,500 birds. To account for this variability, average bird numbers and daily feed consumption were calculated for each poultry type. For instance, a flock of 200 broilers consumed over 20 kg of feed per day, while 1,650 layers consumed 112 kg based on the data collected from the respondents. For poultry feed sellers, who were retailers, estimating quantities capacity proved difficult due to fluctuations in market demand.

3.4 Formulation Compositions

According to the results of the surveys carried out in the three subdivisions, most farmers (68.22%) purchase their inputs separately from the market and formulate their own feed. Formulations used vary according to the type of poultry reared and the growth stage of the birds. A common concern raised by poultry farmers was that the recommended rearing phases were often not followed, due to the high cost of feed. It was also noted that for the same type of poultry, the formulation varies according to the farmer's income, the availability of inputs on the market and also the type of Mineral Nitrogen Vitamin Concentrate (MNVC) commonly known as concentrate, which is made up mainly of proteins (fish and soya meal).

The data revealed no standardized feed formulation for either broilers or layers. Responses varied widely, with each poultry farmer relying either on personal experience or on formulas provided by commercial feed manufacturers. Nevertheless, the raw materials used were consistent across formulations, with the main ingredients being maize, soya, peanuts, bone meal, wheat bran, concentrate, palm oil, oyster shell, cottonseed cake, and palm kernel cake subject to slight variations depending on whether the feed was intended for broilers or laying hens.

3.5 Availability and Current Cost of Protein Sources on the Market

The majority of the respondents were aware of the protein sources they used in their formulations and a small proportion had no idea of the protein sources contained in the formulations. The vast majority of people cited soya and fishmeal as the main sources of protein (Figure 3).

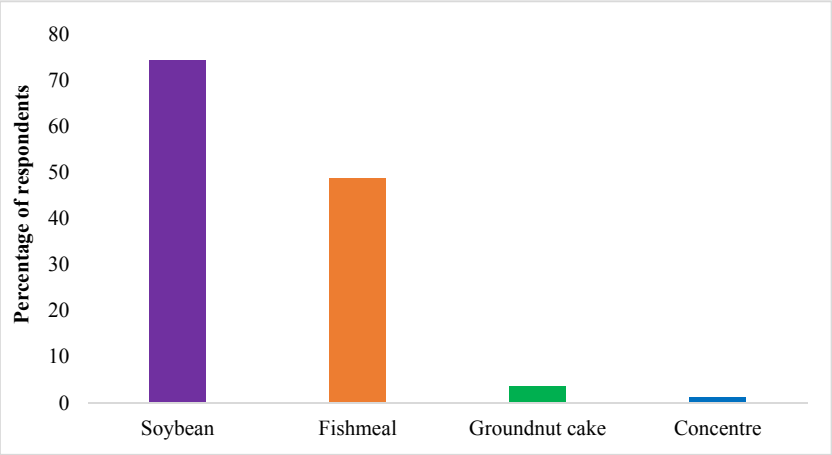

Figure 3. Current protein sources used for poultry feed in Ngaoundere

Concerning the current cost of these proteins on the local market, almost all (98.1%) of the farmers considered that the costs of proteins on the market were high, rather than affordable. The prices per kilogram of protein sources on the market at the time of the study were 500 CFA francs (around 0.76€), 650 CFA francs (around 1€) and 350 CFA francs (around 0.55€) respectively for fishmeal, soya meal and groundnut meal. Furthermore, due to high prices, poultry farmers reported that they were often forced to omit certain ingredients or adjust quantities when formulating feed, in an effort to remain profitable. This practice inevitably affects the quality of the final product.

3.6 The Scarcest and Most Expensive Ingredients

Of all the ingredients used in the formulations, the most expensive is the concentrate (92.3%), which is a composed mainly of fish meal. There were two types: the 5% concentrate, which costs 950 CFA francs (around €1.50) per kg, and the 10% concentrate, which costs 850 CFA francs (around €1.30) per kg. Soya (76.92%), maize (76.92%) and groundnuts (38.46%) were also among the most expensive ingredients according to farmers. For 90% of them, concentrate was the most expensive, followed by soya (40%) and maize (20%). Generally, all the respondents were unanimous, that protein concentrate, soya, maize and groundnuts are the rarest ingredients and therefore the most expensive on the market due to stock shortages and delays experienced by importers of these products (Figure 4).

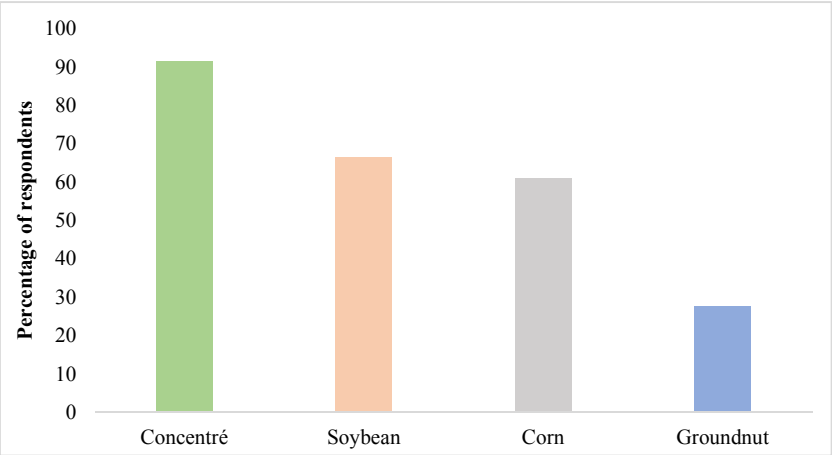

Figure 4. Most expensive ingredients used in poultry feed formulations

3.7 Challenges Encountered by Poultry Farmers and Poultry Feed Sellers

High input costs for feed (84.1%), disease (39%) and difficulty in selling their livestock products (8.5%) were the main problems encountered by poultry farmers. As for poultry feed sellers, 100% mentioned high input costs as the main problems associated with their activity.

3.8 Acceptance of Insect-Based Poultry Feed

All the respondents in this study were aware of insects as a food ingredient for humans and for some in animal feed. Among them, we recorded 4.1% who used insect maggots (*Musca domestica*) in their animal feed because they had heard about them on internet, on television or during their studies/training. The majority of respondents (77%) expressed willingness to use insect-based feed if it became commercially available, particularly if research demonstrated its effectiveness and if the price was affordable.

Based on the results of the Multiple Correspondence Analysis (MCA), the acceptance of insect-based feed among poultry stakeholders varies significantly across socio-professional parameters such as age, sex, level of education, and professional role. Younger participants, particularly those under 40 years old, demonstrate a higher level of acceptance. Regarding education level, individuals with secondary and university-level showed slightly lower rate than those with only primary-level schooling (Figure 5).

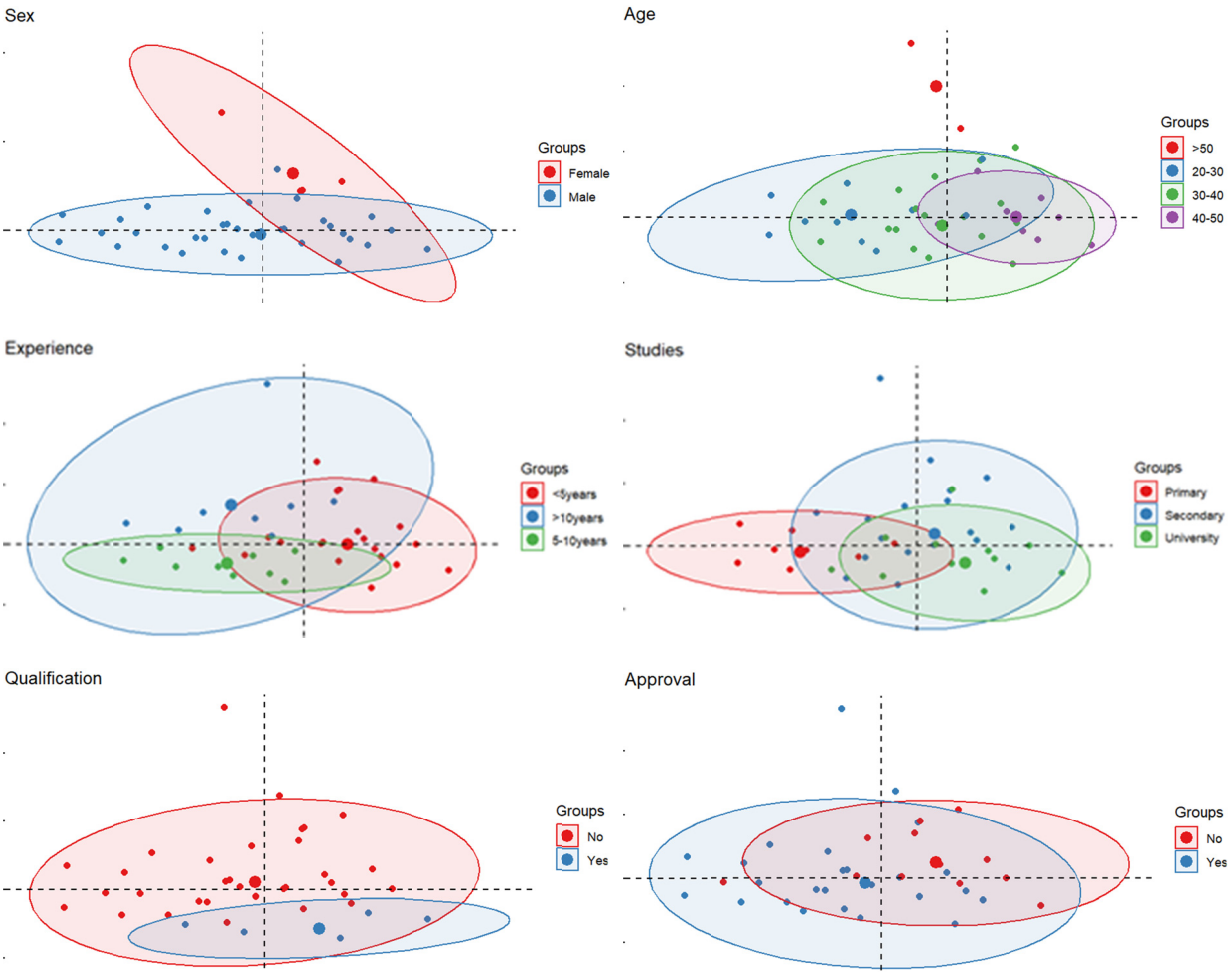

Figure 5. Acceptance level of insect meal among poultry farmers based on age, sex, experience and education level. The MCA showed a high acceptance rate among poultry farmers

All the poultry feed sellers surveyed, regardless of sex, age or level of education, agreed to market such an ingredient if it was available and approved by the authorities (Figure 6).

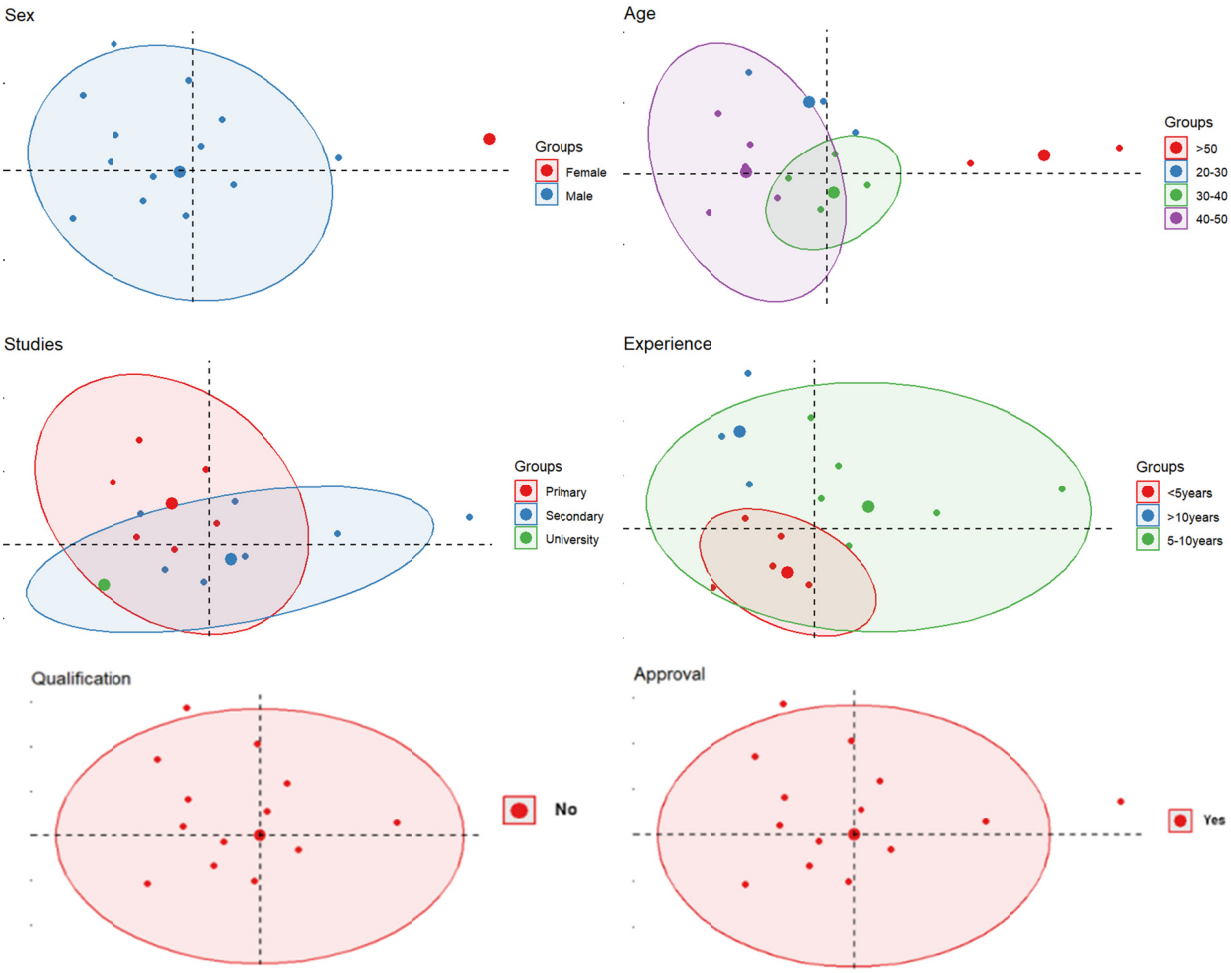

Figure 6. Acceptance level of insect meal among poultry feed sellers based on age, sex, experience, and education level. The MCA revealed a high rate of acceptance

These results clearly show the strong demand for protein ingredients on the local market and that poultry farmers are prepared to use black soldier fly meal as a source of protein in chicken feed. Nevertheless, their statements were based on the quality and cost of the feed and the production capacity of the larvae to meet market demand. Similarly, the performance aspects of insect-based feeds were perceived as more important by farmers. Government approval was also an important consideration for poultry feed sellers.

4. Discussion

4.1 Socio-professional Characteristics of Poultry Farmers and Poultry Feed Sellers

The survey revealed that the majority of poultry farmers were men. This male dominance in poultry farming has also been observed in previous studies on duck farming in Cameroon (Djitié et al., 2015; Katchouang et al., 2015) and quail farming in Benin (Tohoue, 2021). The proportion of women in our study was notably low compared to the 42% reported by Katchouang et al. (2015) in their study on quail farming in the Mfoundi department, Centre region of Cameroon. This difference may be attributed to several contextual factors. First, the Mfoundi department is part of a more urbanized and economically developed region with greater access to markets, training programs, and support services that may encourage women's participation in poultry farming. In contrast, our study was conducted in Ngaoundere, where socio-cultural norms may impose more traditional gender roles, and women may have limited access to land, capital, or decision-making power in agricultural activities (Nahimana et al., 2016).

The relatively high educational level and younger age of poultry farmers present an advantage for the adoption of modern production techniques and the acquisition of new skills (Fouepe et al., 2017; Katchouang et al., 2015). Providing training opportunities, as the study revealed high proportion of poultry farmers without formal poultry

farming qualifications, could further enhance their receptiveness to innovation and strengthen their capacity to assimilate essential technical knowledge (Fouepe et al., 2017). The prevalence of farmers formulating their own feed suggests that introducing new feeds with alternative protein sources could be readily adopted in this region.

The survey revealed that broilers, laying hens, and local chickens were the primary types of poultry reared in the study areas. These birds were mainly produced to supply local markets in the town and surrounding areas, with some also exported to neighboring countries such as Chad and the Central African Republic (GIZ, 2018). A study by Fotsa et al. (2007) have shown that most local chickens are reared in the courtyards of family homes and are used for wedding ceremonies, to ward off curses, for traditional pharmacopoeia and to maintain social cohesion within traditional communities through donations and the reception of distinguished visitors.

The formulations used for poultry feed vary according to two main criteria: the type of poultry reared and the stage of growth of the birds. However, the variation in the information collected shows that there is a lack of standard formulations available to farmers. As a result, farmers rely on their own knowledge learned on the job or on formulas made available by complete feed manufacturing companies. The same observation was made by Tendonkeng et al. (2015), who stated that compound feed manufacturers in West Cameroon used the formulas of service providers and that these formulas are supplied to small-scale producers as a service by these suppliers.

The protein sources used by poultry farmers and poultry feed sellers were soyameal, fishmeal, groundnut meal and concentrate product. This was similar to Tendonkeng et al. (2015), who found that the most common protein sources in the towns of Bafoussam and Dschang were palm kernel meal (89.6%), soybean meal (85.8%), fishmeal (84%), cottonseed meal (82.1%) and groundnut meal (79.2%), followed by concentrate products (56.6%), with soybean meal and fishmeal being the most commonly used protein sources. Their nutritional quality justifying their widespread use by livestock farmers (Tendonkeng et al., 2015). Palm kernel cake, cottonseed cake and groundnut cake are of national origin (Tendonkeng et al., 2015). On the other hand, soya, fishmeal and concentrate products are imported, which makes their prices relatively high on the market (from 500F CFA to 950F CFA per kilogram). This often leads farmers to do without certain ingredients and/or to play around with quantities, with an impact on the yield and quality of the final product. As it is known that feed has an impact on the growth rate and fertility of the animals (Nahimana et al., 2016; Ogle et al., 2004). Although more people are interested in poultry farming sector, the lack of supervision of the sector has given free rein to improvisation and amateurism due to poor organisation as well as the absence of quality standards in the regulations governing the sector (Tendonkeng et al., 2015).

Among the difficulties encountered by poultry farmers and poultry feed sellers, scarcity, the high cost of ingredients on the market and disease were the most frequently cited. Conventional protein sources (soya meal and fishmeal) were the main and most expensive ingredients on the market due to their scarcity. This situation leads to irregularities at local level and farmers are left to fend for themselves in these cases. In addition, the prices of these proteins are constantly rising globally, making them less and less accessible to poultry farmers, who derive very low profit margins from their activity (Onsongo et al., 2018). This major challenge faced by poultry farmers could be addressed by promoting the use of locally available resources such as BSFL in poultry feed. BSFL production is space-efficient, cost-effective, and grounded in circular economy principles, offering high nutritional value while reducing dependence on expensive conventional inputs. In response to the challenges of irregular supply and high costs of conventional protein sources, the use of BSFL in poultry feed could be positively received by farmers as a viable alternative protein option. This will involve raising awareness among farmers in general of the socio-economic and environmental spin-offs, such as the employment opportunities arising from the insect-based food value chain and the recycling of organic waste from their farms.

The acceptance of insect-based feed among poultry stakeholders varies significantly across demographic parameters and professional role. Overall, 76.8% of the stakeholders surveyed were in favor of the idea of using insect-based feeds for poultry. Particularly those under 40 years old, demonstrated a higher level of acceptance compared to older individuals. Younger farmers often face fewer barriers in adopting new technologies and tend to be more exposed to training programs. Interestingly, this study found that individuals with only primary-level education exhibited slightly higher acceptance of insect-based feed than those with secondary or university education. This may be explained by the fact that more educated individuals may exhibit caution due to limited regulatory clarity, perceived food safety risks, or lack of formal endorsement. The majority of respondents (77%) expressed openness to using insect-based feed, likely due to their experience with the challenges posed by irregular supply and the high cost of conventional protein sources. In contrast, the remaining minority appeared more hesitant, possibly due to concerns regarding the production capacity of insect-based feed, its quality and stability, as well as the current lack of clear regulatory guidelines governing its use. As observed in Cameroon, a

comprehensive legislation and quality standards for insect-based feed are still under development. This regulatory gap creates caution among commercial actors of the poultry sector.

Although experiments in rearing insects for animal feed have produced satisfactory results in some regions of Sub-Saharan Africa (Fiaboe & Nakimbugwe, 2017; Kpade et al., 2016; Niassy et al., 2018; Raheem et al., 2018; van Raamsdonk et al., 2017), in Cameroon, action research into the breeding and use of edible insects in animal feed is in its infancy and publications are rare (Polepole et al., 2019). Thus, more in-depth research should be carried out on the rearing capacities of insects on local products, particularly BSFL and on their nutritional values in order to develop them as accessible and sustainable local alternative proteins for local producers.

5. Conclusion and Recommendations

The poultry sector has experienced rapid and consistent growth over the past decades, driven by the increasing global demand for food and nutritional security in response to population growth. This study aimed to assess the acceptability of incorporating insects specifically black soldier fly larvae into poultry feed. It offers insights into the perceptions of poultry farmers regarding insect-based feed as a sustainable and viable alternative. Findings from the Adamawa region of Cameroon indicate that poultry farming, though widespread, remains a relatively young and underdeveloped activity, practiced primarily on a small scale. The most common protein sources, fish meal and soybean meal are expensive and often difficult to obtain due to market shortages and import delays. The study revealed a high level of acceptance among poultry stakeholders regarding the use of insects in feed. Poultry farmers, particularly the younger individuals, demonstrated openness to insect-based proteins. This acceptance represents a significant opportunity for the development of insect farming for animal feed purposes in the region. To capitalize on this opportunity, it is essential to raise awareness among poultry farmers, poultry feed sellers, and consumers about the nutritional, economic, and environmental benefits of insect-based feed. Furthermore, training programs should be implemented to improve poultry farmers' knowledge of poultry rearing techniques, feed formulation, and the safe integration of insect-based ingredients.

However, the findings of this study are context-specific and may not be generalize to other regions with different socio-cultural contexts. Future research should include a broader sample size and cover additional regions of Cameroon in order to generate a larger body of data that could support the government in establishing regulations concerning the use of insects in animal feed in the country. Scientific investigations should also focus on optimizing insect production and processing, as well as exploring the socio-economic impacts of insect-based feed adoption. Public authorities have a crucial role to play in supporting this transformation. They should invest in research on local edible insect species, including their nutritional profiles and potential biosafety concerns, to ensure food and feed safety. Policy frameworks should be established to encourage local initiatives, facilitate insect farming, and reduce dependence on imported feed components. In doing so, government can foster a more resilient and sustainable livestock sector capable of meeting the country's growing demand for animal proteins.

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Appendix A

Poultry Stakeholders Survey

Aim of the Survey

The aim is to obtain information on: i) the dependence of farmers on imported protein complexes and other fishmeal; ii) acceptance of a new formulation based on insect meal.

(1) General information about the respondent

- Sex: ☐ Male ☐ Female
- Age (years): ☐ Between 20 and 30 ☐ Between 30 and 40 ☐ Between 40 and 50 over 50
- Id: ☐ Breeder ☐ Feed seller
- Site of the activity (neighborhood): ..... Municipality: .....
- Level of education: ☐ Primary ☐ Secondary ☐ University
- Experience: ☐ Less than 5 years ☐ Between 5 and 10 years ☐ More than 10 years
- Do you have any training in poultry farming? ☐ Yes ☐ No

(2) Organization of the activity

- Type of farming (poultry production)

(a) What species of poultry do you breed?

☐ Layer hens ☐ Broiler chicken ☐ 21-day-old chicks ☐ Quails

☐ Ducks ☐ Geese ☐ Turkeys ☐ Local chicken

(b) What is the size of your herd? ..... subjects.

(c) How much animal feed do you use per batch? ..... kgs.

(d) What protein sources do you use for your formulation?

(e) What is its current market cost? ☐ Affordable ☐ Expensive

- What are the major difficulties you are currently facing?

.....

.....

(3) Perspectives

(a) Do you formulate your own feed? ☐ Yes ☐ No

(b) Will you agree to use an ingredient like insect meal to feed your chickens? ☐ Yes ☐ No

(c) Will you agree to commercialize an insect-based meal feed? ☐ Yes ☐ No

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Authors Contributions

M.E. and Prof. L.N.T. were responsible for study design and revising. M.E. was responsible for data collection. M.E. conceptualized the manuscript. M.E. prepared Tables 1 and 2. M.E prepared Figures 1, 2, 3, 4, 5 and 6. Prof. K.T., Prof. T.H. and Prof. L.N.T. edited later drafts. All authors read and approved the final manuscript.

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Competing Interests

Authors declare that they have no competing interests that could have appeared to influence the work reported in this paper.

Informed Consent

Obtained.

Ethics Approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

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Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data Sharing Statement

No additional data are available.