FARMERS' PERCEPTIONS AND PREFERENCES FOR COMMERCIAL INSECT-BASED FEED IN KIAMBU COUNTY, KENYA

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DECLARATION

This thesis is my original work and has not been submitted for award of a degree in any other University.

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To my late grandfathers (Okello and Odumbe) for their steadfast belief in the power of education that has been reinforced by Okello N'Jaramba and Thamasis Odumbe.

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LIST OF ACRONYMS AND ABBREVIATIONS

BSF	:	Black soldier fly
CE	:	Choice Experiment
CAADP	:	Comprehensive Africa Agriculture Development Program
CIDP	:	County Integrated Development Plan
CVM	:	Contingent Valuation Method
FAO	:	Food and Agriculture Organization of the United Nations
GDP	:	Gross Domestic Product
IBF	:	Insect-based feed
icipe	:	International Centre for Insect Physiology and Ecology
IIA	:	Independence of Irrelevant Alternatives
KEBS	:	Kenya Bureau of Standards
KNBS	:	Kenya National Bureau of Statistics
KSh	:	Kenyan Shilling
MT	:	Metric tons
PCA	:	Principal Component Analysis
RP	:	Revealed Preference
RPL	:	Random Parameter Logit
RUT	:	Random Utility Theory
SDG	:	Sustainable Development Goal
SFM	:	Soybean and fish meal
SP	:	Stated Preference
TPB	:	Theory of Planned Behavior
WTP	:	Willingness to Pay

ABSTRACT

Feed accounts for at least 70 percent of chicken production costs due to the expensive protein ingredients of soybean and fishmeal (SFM) that are key in commercial feed formulation. Expensive feed has seen chicken farmers scale down production or abandon the enterprise despite the current high and projected increased demand for chicken products of 121 percent by the year 2050. Insect protein from the black soldier fly (BSF) larvae has been identified as the best alternative source of protein that will reduce production costs by at least 17 percent. Previous studies have focused on the nutritional profile of the BSF and consumers' willingness to pay (WTP) for the end-products of chicken reared on insect-based feed (IBF). Little is known on farmers' perceptions and WTP for IBF in chicken production in Kenya. To address this gap, this study examined farmers' perceptions of commercial IBF and their WTP for commercial IBF attributes. Cross-sectional data was collected through a series of multi-stage sampling from 314 predominantly chicken farmers in Kiambu County, Kenya. To assess farmers' perceptions of commercial IBF, the study employed the principal component analysis (PCA) to develop perception indices that were subsequently used in multiple regression analyses. The choice experiment (CE) valuation method and the random parameter logit (RPL) empirical model were used to evaluate famers' WTP for commercial IBF attributes. The results show that over 90 percent of the farmers were ready and willing to use IBF. The PCA identified feed *performance*, social *acceptability* of the use of insects in feed formulation, feed *versatility* and *marketability* of products reared on IBF as the key attributes that would inform farmers' purchase decisions. Awareness of IBF benefits, group membership, off-farm income, wealth status and education significantly influenced farmers' perceptions of IBF. Results from the RPL revealed that farmers were willing to pay premium prices between Ksh 35 and Ksh 345 for IBF in the form of either pellets or mash, feed explicitly labelled as containing insects, feed mixed with SFM and dark-colored feed. Further analysis generated the compensating surplus whereby policy scenarios that consider farmers' profits, environmental sustainability and chicken welfare aspects are preferred. The findings established here underscore the importance of conducting *ex-ante* behavioral analysis for innovations prior to their commercial release for successful uptake. Hence, interventions such as experimental demonstrations that increase farmers' technical knowledge on the productivity of chicken fed on IBF are crucial to reducing farmers' uncertainties towards acceptability of IBF. Partnerships with resource-endowed farmers and farmer groups are recommended to provide wider sensitization to improve knowledge sharing on IBF. Collaborations to open communication platforms between local artisans and feed regulators and millers to facilitate the use of local machinery for feed pelleting and efficient grounding of fatty IBF are suggested, among strategies of developing certified logos for ease of IBF identification and researching on the appropriate proportions of insect and SFM protein for optimal chicken performance. The study provides empirical evidence for the harmonization of the infant regulatory framework by the Kenya Bureau of Standards to guide the standardization process of use of insects in commercial feed. The national government could implement a nation-wide value chain mapping exercise for the poultry sub-sector to update the contribution of poultry to the economy and to also identify opportunities and challenges faced by other poultry breeds like the indigenous chicken.

Key words: Black soldier fly, chicken, Insect-based feed, perceptions, willingness to pay.

CHAPTER ONE: INTRODUCTION

1.1 Background

Among the livestock species, the poultry sub-sector is projected to record the highest growth rate of 121 percent (Mottet and Tempio, 2017) by 2050. Consequently, more and special attention has been directed towards the sub-sector. Consumers' preference for healthy animal proteins has favored the growth of the sub-sector (Dorper, et al., 2020). The short production cycle that characterizes poultry production has further contributed to it being among the fastest growing agro-enterprises. During the period 2008-2018, the sub-sector recorded the largest growth of approximately 41 percent and 24 percent for meat and egg production, respectively, in the global arena (FAO, 2020). As a result, new technologies are being developed to match production and demand for the products in a sustainable manner, even though this still remains a challenge.

Poultry is among the leading livestock sub-sectors in the Kenya owing to its dominance by smallholder farmers (International Livestock Research Institute [ILRI], 2022). Poultry production, together with other livestock animals, contribute about 12 percent to the national gross domestic product (GDP) and 42 percent to the agricultural GDP (ILRI, 2022). Both urban and rural dwellers engage in chicken production which contributes to household food and nutrition security either directly or indirectly through food and incomes, respectively (Omondi, 2018). Poultry production plays a crucial role in reducing the gender gap in agriculture more so because women are particularly more involved in the enterprise than men because of its less intensive nature (Waithanji et al., 2019; Omondi, 2022). Chicken is the most popular and wide spread type of poultry and is usually a representative of the entire poultry sub-sector. Despite the optimistic projections of increase in consumption of chicken meat by the year 2030, the country is unable to meet the demand for chicken products. For instance, Kenya only produced about 64 percent of chicken meat indicating a seven percent drop compared to production of the previous year in 2019 (Republic of Kenya, 2020). The country, therefore, remains a net importer of chicken products from neighboring countries like Tanzania, Uganda and Zambia (Republic of Kenya, 2019a).

This study focused on the exotic commercial chicken production of layers and broilers species which are mostly reared for income generation in Kenya (Onono et al., 2018; Ndukui et al., 2021). Efforts by the government to increase the production volumes of locally-produced chicken products implies that demand for feed ingredients will increase for commercial feed production. Moreover, chicken production remains the largest user of commercial feed whereby 71 percent of feed is used in the sub-sector (Makkar, 2018). The Kenya Markets Trust (2016) records monthly feed production at almost 65,000 metric tons (MT) and indication that feed manufacturers utilize less than 70 percent of their capacity, a situation brought forth by lack of enough feed ingredients in the country. Importing the deficit from neighboring countries is vulnerable to unforeseen irregularities along the cross-border supply chains.

The protein-rich ingredients, particularly soybean and fishmeal (omena), form the main protein component of chicken feed. However, these ingredients are not only limited for use in chicken production but also face competition from human food systems (Van Huis, 2020). For instance, in 2017, the country imported 75 percent and 67 percent of soymeal and fishmeal, respectively (Kenya Markets Trust, 2020). This has ultimately translated into rising prices of feed. Feed already accounts for at least 70 percent (Ssepuuya et al., 2017) of the production costs and a further increase in this cost component threatens the sustainability of the enterprise and consequently the livelihoods of farmers.

The aforementioned issues underscore the immediate need for a cheaper alternative source of protein ingredients. There is overwhelming research on the use of insects, particularly the black soldier fly (BSF) which will be the focus of this study, as the source of protein in feed (Van Huis, 2020; Smetana et al., 2019). Even though insects have been fed to chicken in traditional animal husbandry, research has now focused on their sustainable and viable mass production (Verbeke et al., 2015). Within Sub-Saharan Africa (SSA), it is noted that with increased and timely dissemination of appropriate information, the insect-based feed (IBF) sector has the potential of reducing chicken production costs by 17 percent, contributing to youth employment, food security and poverty alleviation (Abro et al., 2020; Gasco et al., 2020; Onsongo et al., 2018). For instance, integrating BSF larvae in commercial feed is projected to increase Kenya's annual total income by at least US$69 million, which represents a rise of not less than seven percent of chicken's contribution to GDP besides creating a minimum of 3,300 additional jobs and increasing food security by approximately 35,000 tons of available cereals for human consumption (Abro et al., 2020).

1.2 Statement of the research problem

Feed scarcity creates uncertainties for smallholder chicken producers who supply over 70 percent of the chicken products in Kenya (Republic of Kenya, 2019a). This situation has forced them to either scale down on production or abandon the enterprise altogether, thereby disrupting local supply and their source of livelihood. Research and innovation of cost-reducing technologies together with use of locally available feed ingredients is encouraged as a mitigation strategy to address the challenge (Republic of Kenya, 2019a). The changing nature of rearing chicken in confined spaces and the preference for rearing commercial chicken which are suited for intensive production system has reduced the freedom of chicken scavenging on insects to increased use of commercial feed (Waithanji et al., 2019; Carron et al., 2017).

Integrating insects in their processed form with other feed compounds to develop a commercial IBF brings in a novel dimension of retaining traditional protein sources for chicken feeding and nutrition. Despite the estimated economic gains the emerging insect industry is expected to generate, little information is available on farmers' perceptions and willingness to pay (WTP) on the use of IBF in chicken production in Kenya. Madau et. (2020) observe that studies on farmers' potential use of IBF are scarce yet so pertinent if the perceived benefits of IBF are to be realized on the scale projected. In particular, Meijer et al. (2015) emphasized on the importance of interacting farmers' intrinsic features like perceptions with their socio-economic and institutional characteristics in order to target innovations accordingly to promote uptake. Other studies have further shown that understanding individuals' subjective perceptions is a requisite for the acceptability of the use of innovations such as insect protein in chicken production (Domingues et al., 2020).

Based on extant literature, the study by Chia et al. (2020) is the closest to the current study in Kenya. The authors characterized farmers' knowledge and evaluated farmers' WTP for IBF as a wholesome product based on the contingent valuation technique. Even though farmers in that study expressed positive WTP for IBF, knowledge of their preferences for particular features that they are willing to trade-off is scarce in literature. This is despite the fact that such information allows for possible adjustments and improvements in the product before it is introduced into the market (Otieno and Oluoch-Kosura, 2019).

Farmers continue to express demand for products with characteristics that are appropriate and affordable to them, by essentially breaking down a product into various components and basing decisions on the components that are appealing and satisfy to their utility. Based on this fact, the study sought to use the stated preference method of choice experiment (CE) to elicit chicken farmers' WTP for IBF attributes.

1.3 Purpose and objectives of the study

The purpose of this study was to examine farmers' perceptions and preferences for commercial insect-based feed in Kiambu County, Kenya. The specific objectives were:

1. To assess factors influencing farmers' perceptions of commercial insect-based feed.
2. To evaluate farmers' WTP for commercial insect-based feed attributes.

1.4 Hypotheses to be tested

1. Social, economic and institutional factors, taken singly, do not influence farmers' perceptions of commercial insect-based feed.
2. Farmers are not willing to pay for commercial insect-based feed attributes.

1.5 Justification

The potential of using insects in feed production aligns well with the current agenda of transforming food systems through the use of innovative practices to ensure chicken production is more sustainable, equitable and optimizes human, animal and planetary health. The use of insects enhances biodiversity and reduces pressure on natural resources and greenhouse gas emissions hence reinforcing the Nationally Determined Contributions under the Paris Agreement and Kenya's Medium-Term Plan III on technologies that are clean and climate-smart (Republic of Kenya, 2018; UNCC, 2020). This will contribute to achieving the African Union's Comprehensive African Agriculture Development Program (CAADP), the sustainable development goal (SDG) Number Two and Kenya's Big Four Agenda unified goal of increasing food supply, reducing hunger and nutrition security (Republic of Kenya, 2017; UNDP, 2015; African Union, 2003).

The Kenya Livestock Policy (Republic of Kenya, 2019a) endeavors to transform the chicken sub-sector into a commercial undertaking by integrating indigenous knowledge with modern innovations in order to build farmers' confidence in the innovations. The findings established here from the interactions between farmer-based intrinsic and socio-economic and institutional factors provide avenues through which such a policy mandate can be achieved. Understanding the role that farmers play within the process of product development and consequently their implementation helps in communicating key insights for a robust policy framework that will be useful to research institutions such as *icipe*, insect farmers, feed regulators and feed manufacturers.

The findings will further inform the stakeholders of the areas to prioritize on when disseminating information on commercial IBF. Accordingly, the National Agribusiness Strategy prioritizes the need to include smallholder farmers in the research agenda (Republic of Kenya, 2012a). The African Union's Agenda 2063 (Aspiration 1) aspires to build frameworks that improve agricultural research systems for the dissemination of appropriate technologies and supporting farmers to adopt them (African Union, 2015). The realization of this goal is based on findings such as the one on farmers' preferences for IBF whereby the specific features are identified and communicated to the relevant stakeholders, especially the feed millers who will be able to meet the market specifications of farmers.

At the County level, the study informs the critical review of the Kiambu County integrated development plan (CIDP) of 2018 to 2022 to provide a comprehensive framework of improving the lucrative chicken sub-sector in close liaison with the Kenya Bureau of Standards (KEBS) which regulates feed quality. Additionally, the CIDP aims to enhance farmers' capacities in modern and trustworthy farming methods by identifying mechanisms for reducing the cost of inputs. Through this study, farmers will be motivated to engage in insect production not only as an income diversification strategy but also to reduce the expenditure on feeds.

1.6 Organization of the study

This thesis is organized in a paper format and has five chapters outlined as follows. Chapter one provides the overall background information, the statement of the research problem, objectives, research questions and hypotheses, the rationale for the study and the organization of the thesis. The next chapter provides a review of key knowledge gaps in insect-based feed, application of theories underpinning the objectives of the study and the various analytical approaches used. Chapter three provides insights into the execution of the first objective. The second paper, based on the second objective is carefully outlined in the succeeding chapter. Finally, a general discussion, conclusion, recommendations and areas for future research are presented in chapter five.

CHAPTER TWO: LITERATURE REVIEW

2.1 Review of the insect-based feed policy environment

The BSF larvae has commendable properties including high levels of crude protein (Makkar et al., 2014), short reproduction cycles (Wang and Shelomi, 2017), ability to valorize organic streams and it is widely available in the ecosystem (Van Huis, 2020). The IBF is an emerging practice in the formulation of chicken feed in response to the changing consumption patterns. Although recent studies on performance of chicken fed on IBF have shown that it improves the egg and meat quality (Gasco et al., 2019; Mwaniki et al., 2018; Makkar et al., 2014), such studies were based on experimentally controlled environments that do not reflect farmers' ideal contexts; thereby constraining replicability and representativeness of the results (Gasco et al., 2020; Alomia-Hinojosa et al., 2018).

In developed countries, substantial progress has been achieved with respect to the production side of the IBF and its use in chicken production. Until recently, IBF in the European Union was only allowed in the rearing of fish and as an ingredient in pet food. This was mostly attributed to historical safety issues (mad cow disease outbreak) associated with use of animal by-products in commercial feed. However, this was before there was sufficient evidence that insets did not pose such risks (Van Huis, 2020). However, based on recent empirical findings from a plethora of research studies, legislation in the region currently permits the use of insect protein in chicken feed and other livestock like pigs (International Platform of Insect for Food and Feed [IPIFF], 2021). Studies have established that there is no direct link between the use of insect protein and microbial infection in human because chicken and other monogastric animals are efficient in breaking down the crude protein and fatty compounds found in insects; an attribute that is associated with chicken's natural preference for scavenging on insects (Cullere et al., 2016). Moreover, the willingness of consumers and farmers alike to accept and use IBF in chicken production further expedited the regulatory process to accommodate insect protein in commercial feed formulation (Dorper et al., 2020; Sogari et al., 2019). This goes to show that advancement in empirical research plays a fundamental role in policy design and legislation, particularly when introducing novel foods.

In developing nations like Kenya, there is substantial commercial production of the BSF by various companies like Sanergy. Consequently, the regulatory institution (KEBS) has spearheaded the formulation of standards to guide this new environment. Thus far, KEBS has produced two draft standards guiding the use of insects in food and feed: Dried insect products for compounding animal feed – Specification (KEBS, 2017); and Production and handling of insects for food and feed – Code of Practice (KEBS, 2020). The former document was necessitated by increased attention of mass production of insects as an alternative source of protein and their use in feed. The document explicitly highlighted the need for more evidence-based research for future revisions of the document. The latter policy guide, code of practice, transitioned into addressing the need to ensure the safe use of insects for food and nutrition security. The document makes reference to the IPIFF framework for use of insects in feed and further provides a detailed overview of how insects should be produced and post-handling methods for safe use in commercial feed by various stakeholders, among them farmers.

Livestock policies in SSA have a special emphasis on the need to transform the sub-sector from a subsistence level to a commercial (market-oriented) undertaking by employing various modern technologies and innovative practices (Republic of Kenya, 2019a). The focus of this policy is premised on the notion that commercialization is seen as a pathway out of poverty because of its positive association with wealth status among farmers (Cazzuffi et al., 2020). The policies further aim to increase the integration of indigenous knowledge in innovation strategies aimed at enhancing farmers' technical production skills (Republic of Kenya, 2019a).

In a pioneering study, Abro et al. (2020) quantified the potential economic benefits expected from commercial insect-based feed for developing countries. Using short and long-term projections of five percent and 50 percent replacement of the conventional feed sources with BSF larvae, the study made hypothetical calculations of the macro benefits in terms of employment, food security, economic growth and foreign currency savings to be realized. For instance, partial adoption of BSF larvae in commercial poultry production will provide job opportunities to about 3,300 people, recycle at least two million tons of bio-waste, increase foreign currency savings by approximately one million (US$) by reducing the importation of feed and inorganic fertilizers. These projections provide optimism for the urgency of inclusion of insect protein in commercial feed formulation, however, before these macro benefits ca be actualized, it is important to assess whether smallholder farmers are willing to change their current practice to accommodate IBF.

Selaledi et al. (2021a) reported that the inclusion of insects in feed provides an important bridge between scientific and traditional knowledge, which is crucial for the sustainability of novel innovations like IBF. Additionally, market-driven advancements that aim at expanding the livestock sub-sector have strong associations with welfare and resource use management (Enahoro et al., 2019). However, both animal welfare and environmental management concerns remain elusive within livestock production in SSA as majority of the policies lack an appropriate framework that integrate these crucial components into a sustainable sector-enhancing strategy (Selaledi et al., 2021b).

Considering that farmers have traditionally harvested insects to supplement livestock diet particularly in the growth of chicken (Dao et al., 2019; Pomalégni et al., 2018; Sebatta et al. 2018) and being cognizant of the need to conserve biodiversity (Selaledi et al., 2021a), the present study aims to understand how farmers value innovations which not only incorporate indigenous methods but also consider their purchase behavior that drives their commercial feed preferences. A better understanding of the interactions presented by IBF forms a wider part of the efforts to create several scenarios to accommodate policy options for a sustainable chicken sub-sector and emerging insect industry (FAO, 2017). Indeed, Sheahan and Barrett (2017) posited that sectoral policies play a more significant role in influencing the use of inputs as opposed to household, farm or market characteristics.

According to Wilderspin and Halloran (2018), context-specific regulations ought to be emphasized due to the cultural differences associated with insect consumption, more-so if insect-based products are to be sustainable food systems. Additionally, such regulations have been reported to influence farmers' attitudes and consumption behavior (Selaledi et al., 2021a; Nakimbugwe et al., 2020). However, the fact that studies on consumers' preferences and WTP for IBF are limited (Madau et al., 2020) constrains the regulatory environment for IBF. Furthermore, the absence of a legal framework that facilitates the engagement between the national government and the players in the feed industry (Kenya Markets Trust, 2016) inhibits the multi-stakeholder coordination system that is crucial for a policy design process.

2.2 Review of literature on insect-based feed

Disgust and dislike towards insect is a major hindrance towards accepting insect-based products (Kornher et al., 2019). Alternatively, consumers have shown preference towards "invisible" insects whereby the insects are used in compounded feed and consequently do not appear in the end-products that they consume. In Kenya, despite insects been traditionally harvested and collected from the wild to feed chicken as nutritional feed supplements (Waithanji et al., 2019), their use in commercial feed formulation as sources of protein is a relatively new concept.

Considering that use of commercial feed is an investment and a critical production input, particularly for commercial birds, farmers expect economic returns through the sale of chicken products. Recently, Mutisya et al. (2020) noted that indeed the use of insect meal in commercial feed has the advantage of generating revenues to farmers and it is competitive with conventional feed. The evidence suggests that IBF is a suitable alternative to conventional feed and that its availability in the market has the potential of meeting the needs of different farmer segments in the market. Whereas the study was evaluated in an experimental context, it becomes important to understand whether such farmers are willing to take the risk and invest in the modified feed. This way, the study not only brings out a binary situation of whether or not the farmers are willing, but also presents some important underlying patterns that are useful in understanding farmers' feed-purchasing behavior.

Farmers' acceptance and *ex-ante* studies on IBF are paramount because they provide policy design strategies for policy makers and other relevant stakeholders necessary to promote the uptake of IBF once it is available in the market for commercial exchange (Domingues et al., 2020). As mentioned earlier, some studies have investigated farmers' acceptance of IBF. Majority of such studies have reported positive perceptions and willingness to accept IBF. For instance, Sebatta et al. (2018) found that there is a 70 percent potential demand for the IBF and that 67 percent of the chicken producers are willing to rear insects for feed in Uganda. The study further identified social and economic factors that were likely to favor success of IBF and contribute to improved chicken productivity. These factors included age, farmers' awareness that chicken feed on insects, use of intensive production system and beliefs that insects are nutritious for poultry. The failure of Sebatta et al. (2018) to include institutional variables which are paramount because of their role in providing support and facilitation for chicken production and marketing motivates this study. Additionally, the study was conducted in Uganda and due to geographical differences and farmer heterogeneity, it is important that the study be contextualized to accommodate these differences in Kenya.

In one of the pioneering studies on farmers' acceptance of IBF in Germany, Verbeke et al. (2015) noted that farmers would not be willing to pay more for IBF compared to conventional feed because of the perception that it would be more expensive and competitive, despite their knowledge of the high nutritional value posed by IBF. Such a situation is expected because the introduction of innovations and the modification of existing ones involve the use of unique resources which may be produced by a few individuals before their widespread knowledge. On the contrary, Chia et al. (2020) found that chicken farmers were willing to pay 60 percent more for IBF than conventional feed while using the contingent valuation method in Kenya.

Since insects are part of the traditional food systems in the region, farmers know that their availability will not present challenges. The aim of the current study is to exploit the valuation method that decomposes the IBF into various features for which farmers would be willing to pay. Through this method, it is expected that IBF will be tailored with an emphasis on the features that remain attractive to farmers during their feed purchasing decisions. Moreover, farmers' mean WTP for the different features will be used as a guide in the pricing decision for feed millers and mass insect producers.

Considering that the IBF value chain is emerging in Kenya, evidence provided by Chia et al. (2019) and Nyakeri et al. (2016) indicate that insects like the BSF are available in the wild and can be harvested for small-scale production with the use of low-cost rearing methods. These studies provide relevance particularly in an environment that is currently dominated with concerns over potential of mass production of IBF for commercial use in chicken feed formulation (Chia et al., 2020; Onsongo et al., 2018). Moreover, existing and complementary studies like that of Mawia et al. (2019) who conducted a consumer-based study on the willingness of consumers to eat chicken-meat reared on IBF in Kenya give an impetus to the relevance of the current study, in terms of reducing information asymmetries between farmers and consumers. The findings revealed that consumers had positive preference for the products. The current study puts forth vital evidence for relevant stakeholders to invest in the emerging value chain and consider it as a form of enterprise diversification. Through this, IBF will attract more entrepreneurs, including smallholder farmers, capable of supplying BSF larvae for use in feed formulation.

Research on IBF for chicken production is multifaceted. Besides promoting IBF and its role in chicken production, the study also increases attention to the entire poultry sub-sector. The sub-sector is often lumped together with other livestock sub-sectors thus overlooking its role in household economies, possibly due to the small nature of birds. Moreover, the Kenya Markets Trust (2016) noted that the absence of a framework governing the feed industry and difficulties in obtaining information on the specific ingredients used in chicken feed formulation has largely contributed to the irregularities pertaining to the feed industry: yet the chicken sub-sector is the largest user of commercial feed (Makkar, 2018). The current study contributes to the need of re-evaluating the framework governing the feed industry.

2.3 Theoretical review of literature

The Theory of Planned Behavior (TPB), Expected Utility Theory and Random Utility Theory (RUT) are the most popular theories which have been used to describe farmer acceptance and WTP (Borges et al., 2015; Opiyo, 2014; Irungu, 2011). Risk and uncertainty play the centre stage in the decision-making process under the expected utility. Individuals choose between risky or uncertain prospects by comparing their expected utility values. The expected utility theory has been used in assessing the decision-making process of a farmer in several contexts (Borges et al., 2015). The theory, however, fails to account for the role of socio-psychological factors and usually assumes that utility is a proxy for profit maximization: the central goal to farmers when choosing between different innovations (Borges et al., 2015).

The TPB emphasizes the crucial role played by the intrinsic factors of farmers in decision-making and acknowledges that farmers' goals and objectives are heterogeneous (Kan and Fabrigar, 2017; Ajzen, 1991). The theory provides a comprehensive framework for the relationship between the attitude of a person and underlying perceptions and beliefs in influencing their behavior (Figure 2). Attitudes towards perceived behavioral control, behavior and subjective norms can accurately predict the intentions to perform different kinds of intentions (Ajzen, 1991). The framework in Figure 2 facilitates the characteristics of the farmers and those of the IBF to interact with the farmers' intrinsic features in a manner that informs the likelihood/intention and eventually the decision to purchase IBF (the behavior).

According to Meijer et al. (2015) knowledge, attitudes and perceptions are often studied in the same context and in some cases attitudes and perceptions are used interchangeably because of the i) cognitive component that is associated with the definition of both terms and ii) the similarity in the measurement techniques applied when eliciting/evaluating both techniques.

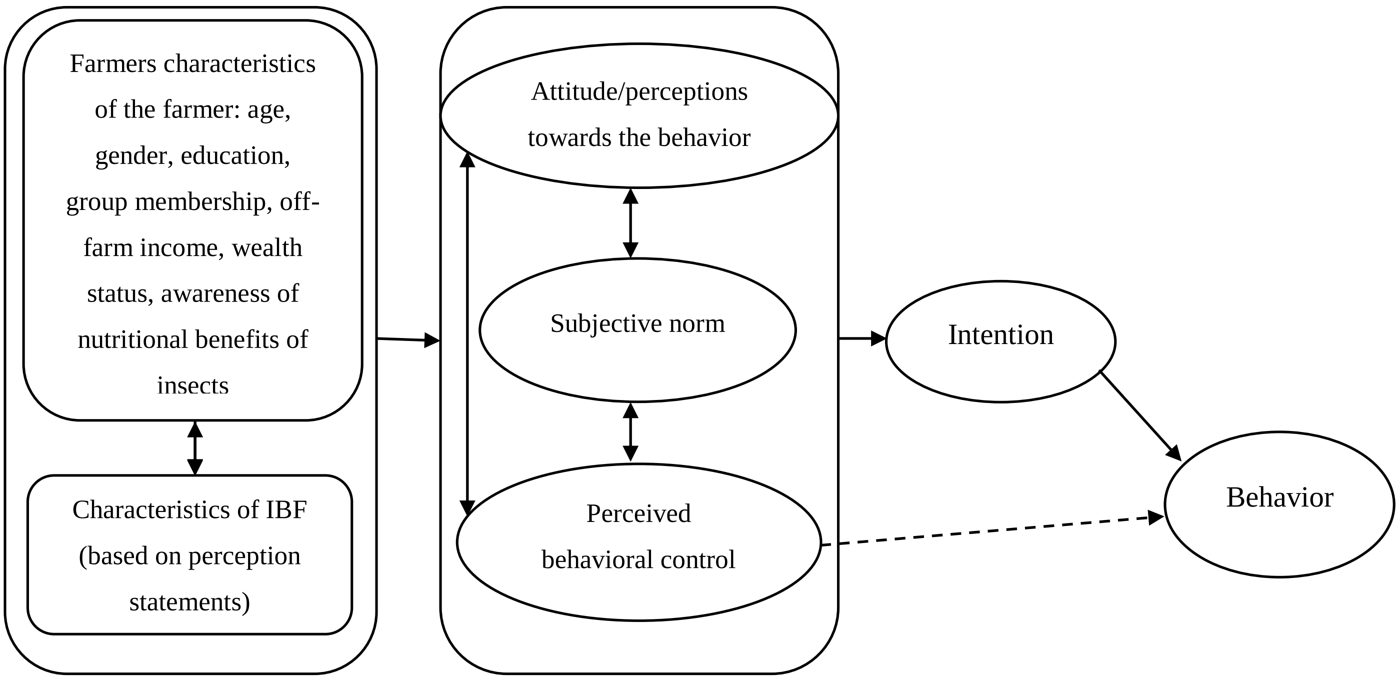

Figure 1: Modified theory of planned behavior (Ajzen, 1991)

The TPB has been applied in various contexts to understand farmers' decision-making such as their intention to use safe chemicals in farming (Savari et al., 2020) and farmers' intention to use pesticides (Bagheri et al., 2019). This study pursued the role that perceptions played in determining farmers' intention to use purchase IBF. The extrinsic aspect includes the characteristics of the farmer and those of the innovation while the intrinsic aspect comprises of farmers' perceptions of the characteristics of IBF.

On the other hand, the RUT (McFadden, 1974) highlights that utility is derived from goods based on their properties or characteristics rather than on the good as an entire product. A farmer chooses to use a new technology if they perceive its utility to be greater than that of the existing technology. This utility is influenced by the attributes of the good in decision-making (McFadden, 1974). The theory forms the basis for choice modeling where a farmer chooses, from a set of alternatives, an alternative that maximizes his/her utility (Hanley, 2001). The farmer has both observable and unobservable characteristics that can influence his/her choice of a utility maximizing alternative (Louviere et al., 2000). The observable characteristics include the optional attributes of IBF that a farmer can visibly identify and assess to make a purchasing decision and the unobservable characteristics include factors such as motivation and ability and are captured by the stochastic error term. Based on the RUT, farmers will be subjected to different alternatives and will choose that alternative from which they expect to derive maximum utility.

2.4 Review of empirical literature on estimating perceptions and willingness to pay

The majority of perception studies have usually gone as far as characterizing perceptions (descriptive analysis) by developing a score/index (Kothalawala et al., 2018; Okello et al., 2015). Studies that have developed an econometric model inclusive of intrinsic variables like perceptions are scarce and it is quite understandable because of the difficulties associated with accurately measuring farmers' intrinsic features and consequent interpretations of the resulting regressions (Meijer et al., 2015; Asai et al., 2014). In such studies, perceptions are often captured using a range of statements measured on an ordinal scale. After-which, a linear reduction technique like the principal component analysis (PCA) is used to identify key behavioral patterns for further interactions with the extrinsic variables. Most of the mentioned studies have opted for the binary modelling frameworks like the logistic probability regression due to the ease of classifying perceptions as either positive or negative, once a binary score has been established based on a particular threshold (see Oo and Usami, 2020; Cullen et al., 2017).

There are a few studies that have retained the continuous nature of the perception indices and proceeded with regression analysis without subjecting the perception index to any threshold (Asai et al., 2014; Abebaw et al., 2006; Flaten et al., 2005). Multiple linear regressions method has been identified as the suitable framework for this analysis because the perception indices generated are usually uncorrelated hence eliminating potential multicollinearity problems (Howley and Dillon, 2012). The same approach is adopted in this study. This study makes a novel approach of combining a linear reduction technique with multiple linear regression to estimate farmers' perceptions on IBF. Chia et al. (2020) used descriptive analysis to characterize perceptions on IBF in Kenya but failed to proceed with regression analysis. Using the ordinary least square (OLS) regression (Greene, 2012) as opposed to the tobit which is useful for continuous data that is within a limited range, this study aims to identify the explanatory variables that are unique in predicting each dimension of perception on IBF for future policy use.

The stated and revealed preference techniques are appropriate for valuing non-market goods and they inform on the design of efficient and effective policies and programs, hence their increased prominence in public policy formulation (Bennett and Birol, 2010). The revealed preference (RP) is determined by observing the individuals' purchasing price and expenditure behavior to gain particular goods and services, whereas the stated preference (SP) is based on the respondent's choice from the hypothetical choice sets. These individuals only state that they would behave in a certain fashion but do not actually make any behavioral changes. The common SP methods include contingent valuation method (CVM) and CE. In the CVM approach, consumers are requested to state the highest amount they would pay after the good is described to them. Some studies on acceptance of IBF have used the CVM method to assess farmers’ and consumers’ WTP for these feeds. For instance, Pomalégni et al. (2018) used the CVM to analyze farmers WTP for IBF in Benin and similarly with Mawia et al. (2019) who used CVM to analyze consumer acceptance of chicken meat reared on IBF in Kenya. More recently, Chia et al. (2020) used the CVM to value smallholders’ WTP for IBF in Kenya.

Given that the use of IBF to make chicken feed is still in pilot stage, the study favored the CE approach. The CE method allows decomposition of a good or service into its characteristics or attributes. The CE method is based on the random utility theory, which posits that given a choice task involving alternative combinations of attributes of a product, a rational individual would choose the option that yields the highest level of utility (McFadden, 1974). Since utility is unobservable, the satisfaction derived by the individual can be inferred from the value represented by the choice made (Hall et al., 2004). This method is detailed in Chapter 4.

Empirical applications of the CE approach are vast in the extant literature. In Kenya, the CE approach has recently been applied in the analysis of various policy issues. These include: consumer preferences for quality and safety attributes (Otieno and Nyikal, 2017), consumer preferences for vitamin A-fortified sugar (Pambo et al., 2017), producers’ WTP for geographical indicators of agri-food products (Maina et al., 2019), local stakeholders’ preferences for foreign land lease design attributes (Otieno and Oluoch-Kosura, 2019) and consumer preferences for chicken welfare attributes (Otieno and Ogutu, 2020). The only empirical valuation of preferences for insect-based livestock feeds is that of Altmann et al. (2019) that applied CE approach to understand WTP for micro-algae in Germany. This study makes a novel application of the CE method to evaluate farmers’ preferences for use of BSF in preparation of commercial chicken feed in a developing country context.

2.5 Study area

The study was conducted in Kiambu County (Figure 1), which was purposively selected because of its dominance in commercial small-scale chicken production in terms of the total number of chicken reared in the country, which is approximately 3.7 million birds (Kenya National Bureau of Statistics [KNBS], 2019). Further, 68 percent of the chicken producers are commercially-oriented; an indication that they purchase commercial feed (KNBS, 2019; Carron et al., 2017). Therefore, farmers in the area were considered as the right target for the valuation of commercial IBF. The county is adjacent to Nairobi city, an urban market that has high demand for chicken products where more than 50 percent consume commercial chicken (Otieno and Kerubo 2016; McCarron et al., 2015). Affordable and quality feed like the IBF has the potential of attracting poor households into commercial chicken production and boost their livelihoods, thus contributing to reduction of the poverty level that currently stands at 23 percent in Kiambu (KNBS, 2018).

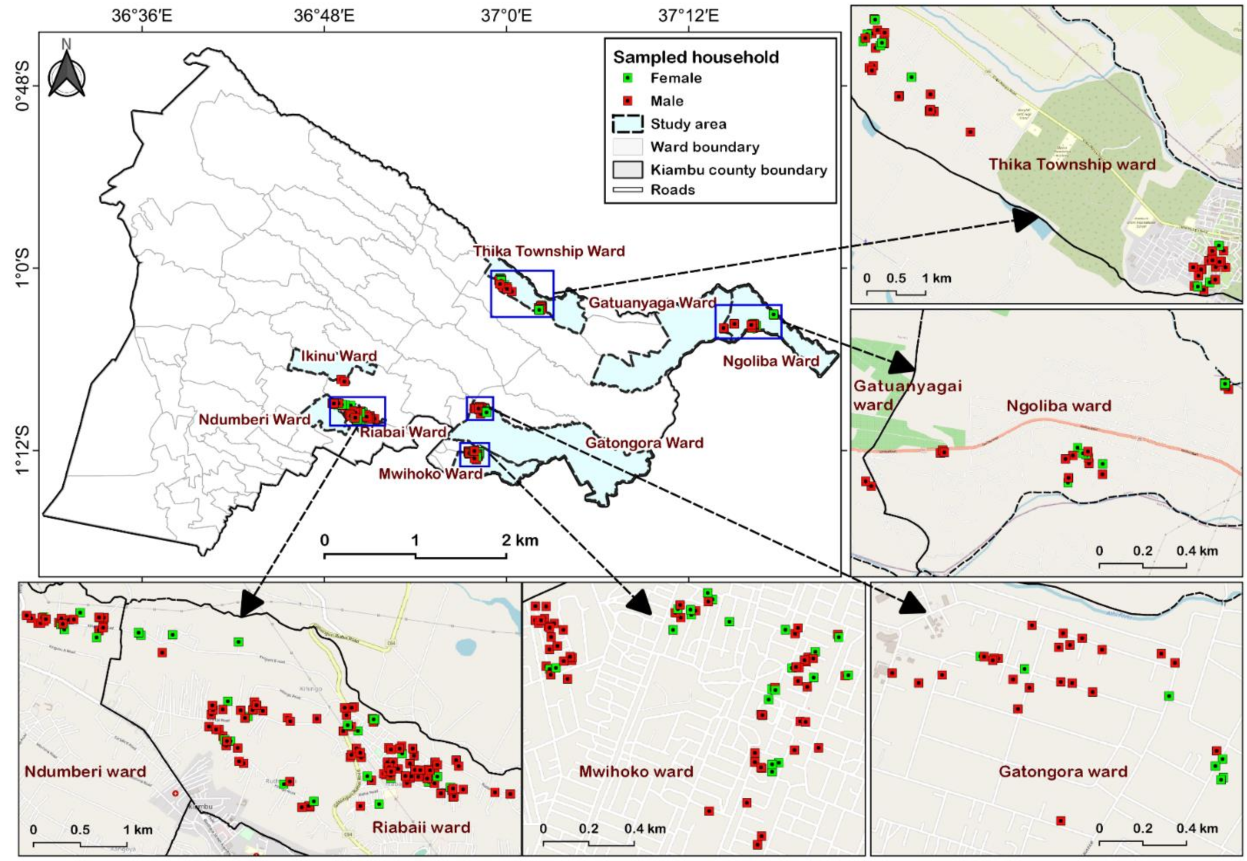

Figure 2: Map illustrating the study sites in Kiambu County, Kenya

CHAPTER THREE: FACTORS INFLUENCING FARMERS' PERCEPTIONS OF COMMERCIAL INSECT-BASED FEED IN KIAMBU COUNTY, KENYA[1]

3.1 Abstract

The utilization of insect-based feed (IBF) as an alternative protein source is increasingly gaining momentum worldwide owing to recent concerns over the impact of food systems on the environment. However, its large-scale adoption will depend on farmers' acceptance of its key qualities. This study evaluates farmer's perceptions of commercial IBF products and assesses the factors that would influence its adoption. It employs principal component analysis (PCA) to develop perception indices that are subsequently used in multiple regression analysis of survey data collected from a sample of 310 farmers. The PCA identified feed *performance*, social *acceptability* of the use of insects in feed formulation, feed *versatility* and *marketability* of livestock products reared on IBF as the key attributes that would inform farmers' purchase decisions. Awareness of IBF attributes, group membership, off-farm income, wealth status and education significantly influenced farmers' perceptions of IBF. Interventions such as experimental demonstrations that increase farmers' technical knowledge on the productivity of livestock fed on IBF are crucial to reducing farmers' uncertainties towards acceptability of IBF. Public partnerships with resource-endowed farmers and farmer groups are recommended to improve knowledge sharing on IBF.

Keywords: environment; insect-based feed; multiple regressions; perceptions; principal component analysis

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3.2 Introduction

Intensification of agricultural production that improves the competitiveness and profitability of livestock enterprises is one option that can increase food production and reduce poverty in Africa (FAO, 2012). Poultry, fish and pig production are the fastest growing agribusinesses in SSA providing income and employment opportunities for the population. In Kenya, the livestock sub-sector contributes about 12 percent to gross domestic product (GDP) and 42 percent of agricultural GDP (ILRI, 2022). In addition, 66 percent of Kenyan households keep at least one type of livestock with 98 percent of the rural households keeping chicken (Republic of Kenya, 2019a). Chicken rearing is one of the most popular livestock enterprises in Kenya due to its low capital and space requirements. The sub-sector employs about two million people (Republic of Kenya, 2008) directly in production and marketing and indirectly through linkages with suppliers of inputs such as day-old chicks, feed and veterinary services.

Kenya’s chicken sub-sector can increase household incomes and contribute to food and nutrition security through the provision of eggs, meat and manure. However, its potential is hampered by the high cost of production with the cost of feed alone amounting to over 70 percent of the production costs (Ssepuuya et al., 2017). Owing to the high cost of commercial feed, chicken farmers in Kenya have resorted to formulating their own feed, and/or the inappropriate administration of growth hormones (Omondi, 2018). The own formulated feed often does not meet the required nutritional requirements for the birds (Kasule et al., 2014). Furthermore, the country’s reliance on cheap imports of feed and protein ingredients from neighboring countries makes local feed production unsustainable (Republic of Kenya, 2019a). The situation is exacerbated by non-tariff barriers (NTBs) to trade that hamper the consistent supply of feed ingredients and unanticipated recent crises brought forth by climate change and global pandemics such as that of coronavirus disease 2019 (Covid-19).

Insects have been proven to be potential alternatives to animal and plant protein sources worldwide (Van Huis, 2020). Although insects occupy 80 percent of the global biodiversity and have been part of traditional delicacies for over two billion people, they are among the most underutilized feed resources (Dobermann et al., 2017; Makkar et al., 2014). The sustainable utilization of insects in livestock feed formulation has the potential to transform the current overreliance on fishmeal and soybean meal to a vibrant circular economy that offers employment opportunities especially for youths and women at the grassroots with effective feedbacks to the environment. The use of insect protein, particularly the BSF, in livestock feed formulation is being explored globally (Aarts, 2020; Domingues et al., 2020; Bbosa et al., 2019).

Several milestones in this regard have been achieved (Ssepuuya et al., 2017; Domingues et al., 2020; Altmann et al., 2019; Biasato et al., 2019). In the European Union, whereas appropriate legislative steps are being initiated to integrate insect protein into feed formulation processes for poultry and pig production, the use of insects in fish feed has been approved (Van Huis, 2020; Boloh 2018; Veldkamp and Bosch 2015). In Kenya, reference (Chia et al., 2019) generated business models for insect-rearing for smallholder farmers in a way that would ensure profitability and environmental sustainability. Nyakeri et al. (2017) demonstrated that the BSF is locally available in wild ecosystems and can be easily harvested for commercial feed production.

Understanding the context and needs of the target groups prior to the release of the innovations facilitates a favorable reception of the technology. Therefore, initiatives on awareness creation to boost farmers' perceptions have been promoted in recent literature (Jha et al., 2020; Oo and Usami, 2020; Llagostera et al., 2019). According to Fatch et al. (2020), understanding farmers' perceptions provides an accurate reflection of their contextual situation, which could be an impediment to the uptake of innovations. Traditionally, insects are associated with disgust (Sogari et al., 2019), dirt and are considered to be pests, hence the belief that they should be eliminated from the food supply chain (Kinyuru et al 2020; Waithanji et al., 2019). Thus, understanding farmers' perceptions of insect-based feed (IBF) is an important starting point in initiatives that seek to improve livestock welfare through conscious feeding practices and effective management of their health (Otieno and Ogutu, 2020; Wambugu, 2019).

Following Oo and Usami (2020), this study defines perception as the cognitive interpretation and understanding of the comparative characteristics of insect proteins in livestock feeds over conventional fishmeal and soybean protein. The study builds on the work of Chia et al. (2020) who described the attitudes and knowledge of livestock farmers towards use of insects as a feed alternative in Kenya. This study examines the factors that can support behavioral change of livestock farmers with respect to improved and cost-effective insect-based feeds by synthesizing evidence collected from chicken farmers in Kiambu County, Kenya. The paper sought to answer two questions namely: "What do farmers think (farmer's general view) about IBF?" and "What are the factors that influence their thinking?"

3.3 Materials and methods

3.3.1 Analytical framework

This study employs multiple regression analysis to estimate the factors influencing farmers' perception of IBF in Kiambu County, Kenya. The dependent variables of the ordinary least squares (OLS) equations are the perception indices composed using a PCA, while the independent variables consist of farm/farmer and technology specific characteristics. Multiple regression is an extension of linear regression that analyses the correlation between more than one explanatory variable. According to Green (2012), the OLS approach is used in estimating parameters in a linear model. This approach is well-suited to cases where the dependent variable is continuous and, in this case, the continuous nature of the perception indices qualifies the use of OLS. The OLS estimates have commendable statistical properties of being best linear unbiased estimators with minimum variance (Greene, 2012; Montgomery et al., 2012). However, despite the distinction of the estimates, further model adequacy checks and validation are necessary following the linear regression to ascertain the appropriateness of the model (Montgomery et al., 2012).

Previous studies have applied factor scores as dependent variables in multiple linear regressions to understand farmers' perceptions. Most recently, Asai et al. (2014) evaluated livestock farmers' perceptions of collaborative arrangements for manure exchange using multiple regressions based on factor analysis in Denmark. Abebaw et al. (2006) combined various farm and non-farm characteristics to compute factor scores that were used to elicit the determinants of coffee farmers' perceptions of risk. Other studies (Flaten et al., 2005) compared dairy farmers risk perceptions with their risk management practices in Norway using a factor analysis. Whereas factor analysis reveals latent variables representing farmers' perceptions of IBF, the OLS permits in-depth exploration of the factors to consider when advising governments, farmers, research institutions and other stakeholders on IBF.

3.3.2.1 The principal component analysis method

The PCA method was applied in this study to generate factors with strong patterns explaining farmer's perceptions of IBF. The PCA is a popular linear dimension reduction technique that reduces an excessive number of correlated variables by building a linear combination of uncorrelated variables that maximize the total variance explained. In doing so, relevant information is extracted from large data and the dimensionality of the data set is reduced by providing new and meaningful variables (Hair et al., 2010). The use of PCA is validated through the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy where a value of at least 0.6 is preferred (Kaiser, 1974). Components with *eigen* values of at least one are retained based on the Kaiser criterion (Kaiser, 1974). Further, the component loadings are subjected to an orthogonal varimax rotation which produces uncorrelated factor scores for ease of interpretation. Domingues et al. (2020) recommends the retention of statements with factor loadings above 0.5 for use in composing perception indices, a threshold adopted in this study.

Following Mwololo et al. (2019), the index was generated using the weighted sum scores criterion (DiStefano et al., 2009) with slight modification relevant to the study context:

$$P_j = \sum_{j=1}^{k} b_k\left(a_{jk} - a_k\right)/S_k \quad (1)$$

where P_j is the perception index for the *j*th farmer, b_k represents the weights/factor loading of the *k*th perception statement; a_{jk} is the response of the *j*th farmer for the *k*th perception statement, a_k

and S_k are the mean and standard deviation of the *k*th perception statement, respectively. The index varies from −1 to +1 and has a mean of zero and a standard deviation of one.

3.3.2.2 Estimation strategy

This study estimates five multiple regression equations. The dependent variables of the five equations are perception indices computed using the PCA method. The indices comprise of four individual IBF component indices derived from the factor scores of four key IBF perception components (performance, acceptability, versatility and marketability) and a composite index of the four individual IBF components. Following Montgomery et al. (2012), the OLS is specified as a linear function of the parameters:

$$Y_n = X_k \beta_k + \varepsilon \tag{2}$$

where Y_n is the *n*th factor score, β_k denotes the vector of the parameters to be estimated; X_k is the vector of the farm/farmer and technology specific characteristics such as: age, gender, years of formal education, income, wealth status, awareness of animal feeding on insects for nutritional purpose and group membership, while ε captures the statistical random term that accounts for measurement error.

3.3.2 Data sources and sampling procedure

The study used survey data from a sample of 310 households in Kiambu County (Figure 1) selected using a three-stage sampling technique. In the first stage, three sub-counties namely: Kiambu Town, Ruiru and Thika Town were purposively selected from a total of 12 sub-counties in the County owing to their proximity to the City of Nairobi and engagement in diverse livestock enterprises; with a large number of chicken. In the second stage, a simple random sampling procedure was used to select two wards in each of the three selected sub-counties. The selected wards were: Riabai and Ndumberi (Kiambu Township); Mwihoko and Gatong'ora (Ruiru); and Gatuanyaga and Karimenu (Thika Town). Since the simple random sampling gives all the individuals an equal chance of being selected to participate in the study, the procedure was employed in identifying the wards and individual farmers to be interviewed (Onwuegbuzie and Collins 2007; Acharya *et al*., 2013). Finally, 50 farmers were selected in each ward from a sampling frame of smallholder chicken farmers that was provided by the sub-county government extension agents through the lottery method of simple random sampling. The sampling frame comprised of 150 to 200 smallholder farmers in each sampled ward. Fifteen extra respondents from Kiambu Township were included in the sample to account for potential non-response (Harapan et al., 2018). A semi-structured questionnaire that contained a mixture of open ended (where the respondent provides their own answer) and closed questions, which restrict the respondent to the choices provided was administered by trained enumerators to the respondents in face-to-face interviews in March 2020.

From the initially expected sample size of 315, the final sample size dropped slightly to 310 after data cleaning. Data were analyzed using SPSS 22 and STATA 14 softwares. Since IBF is not commercially available, the respondents were provided with background information on IBF products prior to the interviews. This background information pertaining to insect-based products included a pictorial description of the insect, its life-cycle and the harvesting stage, insect inclusion in feed formulation, the resulting compounded IBF products, consumers' readiness to purchase the resulting livestock products and the expected effect of the feed on livestock production.

3.3.3 Definition and measurement of variables

The questionnaire included a total of 18 perception statements and respondents were asked to rate their level of agreement on a five-point Likert scale of agreement/disagreement ranging from 1 (strongly disagree) to 5 (strongly agree). Slight modifications were made to transform the responses in the five-point scale to a four-point scale by eliminating the neutral responses to reduce ambiguity and to strengthen the validity of the factor scores. The 18 perception statements are presented and ranked in section 3.4.2, Table 4. The PCA was used to reduce and group the statements into four broad IBF perception attributes (*performance, acceptability, versatility and marketability*) that have 7, 6, 3 and 2 retained factors respectively (see section 3.4.3, Table 5). The statements were based on a wide range of livestock performance indicators such as safety, growth, immunity, feed intake and socio-economic factors such as employment opportunities arising from the IBF value-chain, consumer acceptance of chicken reared on IBF, and environmental sustainability of the feed sources.

Table 1 presents a description of the five perception indices. Each of the four individual perception indices had a mean of zero and a standard deviation of one whereas the composite index had a lower mean of approximately −0.15 and a higher standard deviation of about 7. The values of the scores and the overall index ranged between −3 to +3 and −17 to +17, respectively.

Table 1: Description, mean, standard deviation minimum and maximum values of the commercial insect-based feed perception indicators

Variable	Description	Mean	Std Dev.	Min Value	Max Value
Performance	The nutrient composition and absence of harmful substances that translate into health of the livestock that farmers can monitor.	0.0	1.0	−2.295	2.267
Acceptability	Novel innovations that are guided by the beliefs and social dynamics of the community.	0.0	1.0	−1.896	2.361
Versatility	Multi-purpose feed that considers the differences in livestock breeds and their feed requirements at different growth stages.	0.0	1.0	−2.247	3.275
Marketability	Cautious about how consumers of livestock products may perceive alterations to livestock diets.	0.0	1.0	−2.276	2.221
Perception index	The overall index describing perceptions about the feed as a whole	−0.147	6.921	−16.426	16.495

The farm/farmers characteristics that are later included in an OLS regression model as predictors for farmers' perception of IBF are presented in Table 2. Gender of the household head was measured as a dummy. Chicken enterprise is dominated by women (Ipara, 2019) hence women are more likely to have good perceptions towards IBF. On the other hand, studies like that of (Mwololo et al., 2019) noted that male-headed households were more likely to adopt new innovations in chicken production. Hence, the gender variable was hypothesized to have either a negative or positive influence on perceptions. Age of the household head was hypothesized to have a negative effect on perceptions. Older farmers are more risk averse and show reluctance towards use of new innovations because they may lack sufficient time to observe and appreciate the impact of the innovations (Meseret, 2014). Education of the household head was measured as the years of formal schooling and it was hypothesized to have a positive influence on perceptions. Higher literacy has been found to shape attitudes towards new innovations because of the ability to comprehend technical aspects of the innovations (Meseret, 2014).

Table 2: **Description and measurement of the independent variables used in the linear regression model**

Variable	**Description**	**Measurement**
Age	Age of household head	Years
Gender	Gender of household head	Male = 1; Female = 0
Education	Number of years of schooling of household head	Years
Off-farm income	Whether a household had an off-farm income source	Yes = 1; No = 0
Awareness	Awareness of chicken feeding on insects for nutritional benefits	Yes = 1; No = 0
Wealth status	Wealth index of the household	Index (continuous)
Group Membership	Membership to famers groups	Yes = 1; No = 0

Engaging in an off-farm activity was measured as a dummy variable and was hypothesized to positively influence perceptions. This is because farmers with an off-farm activity are likely to earn more supplementary income that they may invest in new technologies (Ndambiri et al., 2013). Membership to groups was hypothesized to have a positive effect on perceptions. Societal groups positively influence farmers' attitudes towards new innovations because of their fundamental role in disseminating information and empowering members for advocacy roles that may include ensuring their preferences are enforced (Ochieng et al., 2018). Having prior knowledge on new technologies provides a farmer with time to do more research on the benefits and weaknesses of the technology (Okello et al., 2015). Prior awareness is an incentive for good perceptions, hence the hypothesized positive effect. The wealth index was computed using the same principle in equation (1) above. Four items, which have been reported as assets, qualified for the estimation of wealth index: animal housing structure (Carrique-Mas *et al*., 2019); ownership of a television set (Wossen *et al*., 2017); land size (above one acre) (Alwang *et al*., 2019) and total number of livestock units (Ogada *et al*., 2020). Since the index ranges from −1 to +1, any household with a positive wealth index was classified as being wealthy

3.4 Results

3.4.1 Descriptive results

A summary of the socio-economic characteristics of the respondents is presented in Table 3. Over three-quarters of the household heads were male and with an average age of 50 years. Household heads had an average of 12 years of formal education which corresponds to the attainment of a secondary school level of education. Eighty-one percent of the farmers had off-farm income sources that complemented their household income while 46 percent of the farmers were reportedly wealthy. Seventy-two percent of the respondents were members of farmer groups through which they procured inputs and marketed output. While 70 percent of the farmers were aware of the IBF attributes, nearly all respondents were willing to use commercial IBF once available in the market.

Table 3: Characteristics of chicken farmers in Kiambu County, Kenya

Variable	Means and percentages
Average age household head (years)	50.29 (12.10)
Average years of schooling	12.31 (1.44)
Gender of the household head (% male)	77.42
Off-farm income (% yes)	81.29
Wealth status (% wealthy)	46.45
Group membership (% yes)	72.26
Awareness chicken feeding on insects (% yes)	69.03

Note: Standard deviations are presented in parentheses.

3.4.2 Rankings of farmers' perceptions of commercial insect-based feed in Kiambu County

The rankings of the farmers' level of agreement with the importance of various IBF attributes are presented in Table 4. The mean scores ranged between 1.89 and 3.50 with values closer to four indicating more favorable perceptions and values closer to one suggesting less favorable perceptions of IBF, based on a four-point Likert scale. The statement, *"I am willing to use IBF once it is commercially available"* had the highest mean score ranking of 3.5.

The expectation that IBF will lead to employment creation was favorably perceived as indicated by the mean score of 3.43. The mean level of agreement with statements concerning religious and cultural appropriateness of IBF were also high (3.42 and 3.41 respectively), indicating favorable societal acceptance of IBF.

Table 4: Ranked farmers' perceptions of commercial insect-based feed in Kiambu County

Rank	Level of Agreement with IBF Perception Statements	Mean	SD
1	I am willing to use IBF once it is commercially available	3.50	0.611
2	IBF will create new employment opportunities i	3.43	0.623
3	IBF is acceptable in my religion	3.42	0.550
4	IBF is acceptable in my culture	3.41	0.549
5	I will use IBF once the government approves its use	3.29	0.672
6	IBF should have distinguishing features for ease of identification by farmers	3.27	0.712
7	IBF is different from conventional feed	3.10	0.786
8	IBF is safe for livestock use	3.09	0.739
9	My customers will purchase livestock products reared on IBF	3.08	0.737
10	IBF will lead to affordable feed	3.01	0.763
11	IBF is more sustainable in terms of resource use	3.00	0.774
12	IBF will lead to better price for livestock products	2.84	0.749
13	IBF will lead to improved feed intake	2.81	0.771
14	IBF will boost the immunity of the livestock	2.66	0.757
15	Livestock fed with IBF will grow faster	2.48	0.507
16	Insects should be directly fed to livestock without mixing with other ingredients	2.03	0.779
17	IBF should be fed to all types of livestock	1.99	0.820
18	IBF can also be fed to young livestock	1.89	0.775

Note: scale ranging from 1 (strongly disagree) to 4 (strongly agree)
Source: Survey Data (2020).

Government approval and ability to differentiate the new feed from the conventional feed were also important considerations for farmers (mean scores of 3.29 and 3.27 respectively). Farmers' perception of consumer acceptance of chicken products reared on IBF received a mean score of 3.08 suggesting that consumers would have favorable perceptions on livestock products derived from insect-based feeds. The belief that livestock will have improved feed intake and better tolerance towards diseases ranked moderately at 2.81 and 2.66, respectively.

3.4.3 Principal components of farmers' perceptions of IBF and their associated factor loadings

Results of the retained principal components and their respective loadings from each of the 18 perception statements are presented in Table 5. The KMO test of sampling adequacy was 0.856 which is within the recommended threshold of 0.6 to one (Kaiser, 1974). The Bartlett's test of sphericity was significant at one percent level, implying that the items in each group had significant relationship. Further, the Cronbach's alpha, a measure of internal consistency, for each factor score was above 0.5 hence the perception statements were reliable for PCA. Based on the Kaiser criterion (Kaiser, 1974), the retained factors cumulatively explained about 64 percent of the variation. The *performance* component explained the maximum variation of about 35 percent with eight items showing factor loadings above the threshold of 0.5 for retention of statements. Farmers typically agreed with statements such as, "IBF will be more sustainable", "IBF is safe for livestock use" and "Livestock will have improved immunity".

The component of acceptability explained 11.84 percent of the cumulative variation and recorded five statements with factor loadings above the 0.5 threshold. It was common for farmers to indicate that "I will use IBF when the government approves it", "IBF is acceptable in my religion", "IBF is acceptable in my culture" and "IBF will create employment opportunities". Two statements namely; "IBF should be fed to all types of livestock" and "IBF should be fed to young livestock" satisfied the 0.5 factor loading threshold and had the highest contribution to the component on versatility which explained about nine percent of the variation. Marketability recorded two statements with factor loadings above 0.5 and explained the least variation of approximately seven percent in the analysis.

Table 5: Factor loadings of perception statements of commercial insect-based feed after a varimax rotation

	Rotated Components			
Perception Statements	**Performance**	**Acceptability**	**Versatility**	**Marketability**
IBF is more sustainable in terms of resource use	**0.785**	0.193	0.136	0.096
IBF is different from conventional feed	**0.743**	0.162	0.024	0.288
IBF will lead to affordable feed	**0.738**	0.101	0.203	0.265
IBF is safe for animal use	**0.730**	0.121	−0.075	0.008
IBF will create employment opportunities in the new value chain	**0.618**	0.304	−0.135	0.126
IBF will boost the immunity of the animals	**0.598**	0.086	0.251	0.532
IBF will lead to improved feed intake	**0.615**	−0.017	0.479	0.004
IBF should have distinguishing features for ease of identification by farmers	**0.551**	0.387	0.130	0.131
I will use IBF once the government approves its use	0.270	**0.778**	0.052	−0.053
IBF is acceptable in my culture	0.469	**0.703**	−0.099	0.063
IBF is acceptable in my religion	0.495	**0.699**	−0.073	0.062
Animals fed with IBF with grow faster	0.187	**−0.617**	−0.191	−0.175
I am willing to use IBF once it is commercially available	0.486	**0.510**	−0.273	0.224
IBF can also be fed to young ones of animals	0.107	0.065	**0.823**	0.104
IBF should be fed to all types of animals	−0.069	0.159	**0.781**	0.120
Insects should be directly fed to animals without mixing with other ingredients	0.099	−0.0180	0.458	−0.215
IBF will lead to better price for the animal products	0.259	0.066	0.104	**0.838**
My customers will purchase meat and egg products reared on IBF	0.140	0.150	−0.102	**0.809**
Eigen values	6.276	2.131	1.530	1.337
Variance explained (percent)	34.88	11.83	8.50	7.42
Cumulative variance explained (percent)	34.88	46.71	55.21	62.63
Cronbach's alpha	0.877	0.670	0.703	0.749

Notes: Cronbach's alpha = 0.868; Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy = 0.856; Bartlett's test of sphericity: Chi-square (df)= 2671.71 (153).
Source: Survey Data (2020).

3.4.4 Econometric results

The results of the multiple linear regression analysis are presented in Table 6. The factors influencing the individual IBF perception components are in agreement with those of the composite index. However, the coefficients of the latter model are larger than those of the former models, possibly because of the effect of aggregation. The adjusted R-squared values were low (two percent to 26 percent) but within the range of similar studies. For instance, Asai et al. (2014), Abebaw et al. (2005) and Koesling et al. (2004) have reported values of as low one percent for linear regression models of survey data. According to Greene (2012), it is not unusual to observe low adjusted R-squared values in regression analysis using cross-sectional data and in behavioral studies. Nunes (2002) notes that low adjusted R-squared values in factor analysis is an indicates the relevance of the underlying factors in the sense that the perception scores when interacted with observed characteristics contain additional information that is important for the characterization of the farmers' profile. All the models except that of versatility were significant at one percent. The model diagnostic tests were performed to ascertain the absence of correlations among the factor scores and to further justify the use of individual linear regressions (Appendix 3).

Overall, awareness, off-farm income, wealth status and group membership positively and significantly influenced farmers' perceptions of commercial IBF at least at the five percent level. Farmers who were aware of the IBF attributes were more likely to have favorable perceptions of IBF than their counterparts who were not aware. This finding held true for all the perception indices except that on versatility. Similarly, farmers who had an off-farm income source were more likely to have more favorable perceptions on performance and acceptability of commercial IBF than farmers who did not have an off-farm income source. More wealthy farmers had higher

Table 6: **Multiple regression estimates of the factors influencing farmers' perceptions of insect-based feed in Kiambu County**

	Regression Parameter Estimates				
Explanatory Variables	**Composite Index**	**Performance**	**Acceptability**	**Versatility**	**Marketability**
Age	−0.031 (0.029)	−0.001 (0.563)	−0.008 (0.005)	0.005 (0.005)	−0.003 (0.005)
Gender	−0.064 (0.839)	−0.094 (0.131)	0.098 (0.135)	−0.028 (0.0140)	0.047 (0.137)
Education	0.261 (0.246)	−0.008 (0.038)	−0.056 (0.040)	0.107 (0.041) ***	0.112 (0.040) ***
Awareness	3.987 (0.748) ***	0.338 (0.116) ***	0.428 (0.120) ***	−0.101 (0.125)	0.383 (0.122) ***
Off-farm income	4.718 (0.912) ***	0.562 (0.142) ***	0.415 (0.147) ***	−0.082 (0.152)	0.237 (0.149)
Wealth index	1.311 (0.345) ***	0.212 (0.054) ***	−0.018 (0.055)	0.136 (0.058) **	0.027 (0.056)
Group membership	2.548 (0.774) ***	0.318 (0.120) ***	0.270 (0.124) ***	0.019 (0.129)	−0.035 (0.126)
Constant	−10.187 (3.616)	−0.724 (0.563)	0.194 (0.581)	−1.404 (0.604)	−1.699 (0.589)
Adjusted R-squared	0.2676	0.1505	0.0930	0.0221	0.0675
Observations (*n*)	310				

Notes: *** and ** denote statistical significance of variables and models at 1 percent and 5 percent levels, respectively. Standard errors are presented in parentheses.
Source: Survey Data (2020).

likelihoods of having more favorable perceptions on performance and versatility of commercial IBF that their less wealthy counterparts. Finally, households that were members of farmer groups were more likely to have more favorable perceptions on IBF than those households who were not members of farmers groups. This latter finding holds for the performance and acceptability indices.

3.5 Discussion

In conformity with our expectations, the study found that a majority of the chicken farmers in this study had positive perceptions of IBF. Almost all respondents in this study were willing to use commercial IBF once available in the market. The statement, "I am willing to use IBF once it is commercially available" had a mean score ranking of 3.5 out of a possible five further reinforcing farmers' acceptability of IBF. Moreover, farmers expected that the introduction of IBF will lead to employment creation as indicated by the mean score of 3.43. Studies by Chia et al. (2019) and Verbeke et al. (2015) observed that farmers and other stakeholders are willing to rear insects, for income diversification and other economic benefits.

The PCA method was used to compute four perception indices; performance, acceptability, versatility and marketability from retained factors out of the 18 perception statements. The retained factors cumulatively explained about 64 percent of the variation and the four indices were used as dependent variables in the regression analysis. Awareness, off-farm income, wealth status and group membership positively and significantly influence farmer's perceptions of commercial IBF at least at the five percent level (Table 6). These findings suggest that commercial IBF was perceived to be more important than conventional chicken feed by farmers who were educated, aware of chicken feeding on insects for nutritional benefits, those who had an off-farm income source, were wealthy and were members of various societal groups.

The performance aspects of IBF such as improved feed intake and improved immunity of livestock reared on IBF were perceived to be more important to the farmers who were aware of chicken feeding on insects for nutritional benefits. This implies that awareness creation and dissemination is important in promoting use of IBF among chicken farmers in Kenya. Our findings are supported by Chia et al. (2020) and Sebatta et al. (2018) who reported that prior exposure to a particular insect positively contributed to farmers' willingness to use IBF. Similarly, the performance aspects of IBF were perceived to be more important by farmers who belonged to groups than those who were not members of any group. Groups play a crucial role in the transfer of information particularly among smallholder farmers who are often members of more than one group (Onsongo et al., 2018). Wealthier farmers and those with access to off-farm income sources perceived the performance aspects of IBF to be more important than their less wealthy counterparts and those with no access to off-farm income respectively. According to Akhtar et al. (2019), farmers with assets, among them livestock are able to cope with different forms of risks therefore, this group of farmers are keen on understanding how innovations will impact their asset base.

The acceptability elements of IBF were more important to farmers with prior awareness of the nutritional benefits of feeding chicken on insects and those belonging to farmer groups than their counterparts who were not aware. Farmers with off-farm income sources were more keen on the acceptability elements of IBF than those without an off-farm income source possibly because the supplementary income would allow them to purchase IBF once it is commercially available. This is in line with findings by Fahad et al. (2018) that farmers with off-farm sources had more positive attitudes towards new technologies. The versatility features of IBF were more important for wealthy farmers than their less endowed counterparts. Similarly, the more educated farmers perceived the versatility features of IBF to be more important than their less-educated counterparts. High literacy levels facilitate the search, access and comprehension of new and existing information. Educated farmers perceive market research as a critical component to safeguard against economic losses experienced during distress sales (Lubandi et al., 2019).

Finally, the marketability aspects of IBF were perceived to be more important by the more educated farmers and those that were aware of the fact that livestock feed on insects for nutritional benefits than their less-educated counterparts and those who are not aware of this. This might be attributed to their high level of literacy and resource endowments which allow them to access and synthesize market information and to purchase high valued livestock breeds. Characteristics such as consumer acceptance of meat and eggs from chicken reared on IBF and the ability of these products to fetch higher prices in the market were rated highly by more educated farmers than their less educated counterparts.

3.6 Conclusion and policy recommendation

The first objective assessed the factors influencing farmers' perceptions on commercial IBF. Using the principal component analysis technique, perception data revealed that feed purchasing decisions are informed by various elements including the performance of chicken reared on IBF, acceptability, versatility of IBF and marketability of the chicken output. This is a depiction that farmers focus on diverse elements of IBF beyond the external purchase of feed in retail outlets. Hence the importance of *ex-ante* studies in revealing these elements. Further interactions identified socio-economic and institutional factors that influence the perceptions. Farmers who are educated, engage in off-farm activities, are members of societal groups, are aware of the nutritive role of insects in chicken diets and wealthy farmers consider the various elements of IBF to be important.

The study, therefore, rejects the null hypothesis and concludes that socio-economic and institutional factors, taken singly, influence farmers' perceptions of commercial IBF.

Given that perceptions are based on exposure to knowledge, the study recommends that policy interventions by county governments in Kenya should be geared towards increasing farmers' technical knowledge and ability to evaluate the performance of different livestock breeds reared on IBF through technical trainings at group level to capitalize on peer learning. Interventions such as experimental demonstrations that increase farmers' technical knowledge on the productivity of livestock fed on IBF are crucial in reducing farmers' uncertainties towards acceptability of IBF. Public-private partnerships with resource-endowed farmers and farmer groups are recommended to improve knowledge sharing on IBF.

CHAPTER FOUR: FARMERS' WILLINGNESS TO PAY FOR COMMERCIAL INSECT-BASED FEED ATTRIBUTES IN KIAMBU COUNTY, KENYA.

Abstract

High feed costs make chicken production prohibitive especially in developing countries owing to overreliance on protein feed ingredients such as soybean and fishmeal that are characterized by rising food-feed competition and supply chain impediments such as restrictive border policies and the recent Covid-19 pandemic. The use of insects such as the black soldier fly (BSF) as a sustainable alternative protein source has attracted global attention recently. However, there is a dearth of empirical insights on farmers' preferences for commercial IBF. This study evaluated farmers' willingness to pay (WTP) for attributes of commercial insect-based chicken feed in Kiambu county, Kenya using a choice experiment (CE) based on a survey of 314 predominantly chicken farmers. Results show that 93 percent of the farmers are willing to pay for IBF and premium prices range between Ksh 35 and Ksh 345 for IBF in the form of either pellets or mash, feed explicitly labelled as containing insects, feed mixed with soybean or fishmeal and dark-colored feed. This is a pioneering study that specifically values commercial feed based on various components and combinations. The findings provide evidence for multi-stakeholder collaborations to facilitate the creation of an inclusive IBF regulatory framework for sustainable feed and chicken production.

Keywords: Chicken, choice experiment; black soldier fly; insect-based feed; willingness to pay.

4.1 Introduction

Feed forms the most critical component in the nutritional development of livestock. However, human population pressure and competing land uses only leave one-third of global arable land for production of crops such as soybean that provide proteins, which are the key feed ingredients. The main protein ingredients, that is soybean and fishmeal (SFM), constitute the most expensive component of the inputs used in feed production. This is due to competition in their use in food and feed production chains. The food-feed competition for SFM has led to high prices of these feed inputs. Rampant food insecurity challenges in developing countries lead to scarcity of protein-based ingredients for the feed industry, further increasing their prices (Fraval *et al*., 2019). Consequently, there is a dilemma on how to create a sustainable balance between sourcing for raw materials for food and meeting feed requirements for livestock production.

In Kenya, the shift to commercial intensive chicken production system implies a growing demand for commercial feeds (Carron *et al*., 2017). Chicken enterprises contribute to food and nutrition security, as well as incomes to households, and about one-third of agricultural gross domestic product (GDP) in the country (Acosta *et al*., 2021; Carron *et al*., 2017). Further opportunities are expected within the chicken industry, which is projected to record the highest growth of 121 percent within the livestock sub-sector by the year 2050 (Mottet and Tempio, 2017). Developing countries like Kenya will play a key role in spurring this growth at the rate of 2.4 percent compared to 1.8 percent at the global level for chicken production (Mottet and Tempio, 2017). Therefore, continuous feed production is crucial for the sustainability of commercial chicken enterprises, which use up to 71 percent of industrialized feed (Makkar, 2018).

Chicken production costs in developing countries are about 300 percent higher than in the developed countries (Etuah *et al*., 2019). Kenya is a net importer of protein ingredients for feed from neighboring countries like Tanzania, Uganda and Zambia (Republic of Kenya, 2020). Disruptions from international trade disputes and the recent Covid-19 pandemic affect local and regional supply chains (Nordhagen *et al*., 2021) and the final pricing of the feed inputs for local formulation of feed. Further increases in these costs and influx of cheap imports of processed chicken products threaten the margins of small-scale farmers who dominate chicken production in the region (Brauw and Bulte, 2021).

Evidence suggests that the use of locally available feed ingredients, like insect protein, will not only mitigate the chicken production challenges but also address the developmental setbacks of low and middle-income nations (Abro *et al*., 2020; Nyakeri *et al*., 2017; Republic of Kenya, 2019a; Sogari *et al*., 2019; Onsongo *et al*., 2018). Within the Sub-Saharan Africa (SSA) region, the insect-based feed sub-sector can reduce chicken production costs by 17 percent, contribute to youth employment, food security and poverty alleviation depending on timely dissemination of context-specific information (Onsongo *et al*., 2018).

There is overwhelming research on the nutritional and environmental benefits of insect protein particularly the black soldier fly (BSF) larvae, which is the insect of interest in this study. De Marco *et al*. (2015) found that the amount of crude protein and other essential nutrients in BSF larvae meal is higher than those of the other ingredients used in chicken feed formulation; making the insect meal attractive for chicken feed formulation. Insect farming has a low environmental impact owing to the limited requirement for land and water resources, low greenhouse gas and carbon dioxide emissions (Madau *et al*., 2020). Processing of insects for feed promotes the circular economy model, a pertinent approach in a society that is characterized with high food loss and waste in food supply chains (Shumo *et al*., 2019; Spranghers *et al*., 2017). Discarded organic waste accounts for about one third of all food produced for human consumption (World Bank, 2021; Madau *et al*., 2020; Skrivervik, 2020; Spranghers *et al*., 2017), and has negative economic and environmental impact particularly in developing countries, which have inefficient waste disposal and processing strategies. Currently, there is a lag in the adoption of insect-based feed because it is an emerging enterprise in Africa with limited volume available (Tanga *et al*., 2021).

Commercially viable protein alternatives like insect protein that reduce environmental footprint of food systems do not only align with global policies on climate action (World Bank, 2021) but also with national efforts to transform the livelihoods of smallholder farmers in developing countries. For instance, livestock policies in Kenya emphasize the need to transform the sub-sector from a subsistence level to a commercial (market-oriented) undertaking by employing various modern technologies and innovative practices (Republic of Kenya, 2019a). The premise of the policy focus is that commercialization acts as a pathway out of poverty (Cazzuffi *et al*., 2020). Market-driven advancements that aim at expanding the livestock sub-sector have strong associations with welfare and efficient use of resources (Enahoro *et al*., 2019). However, both animal welfare and environmental management concerns remain elusive within livestock production in SSA as majority of the policies lack an appropriate framework that integrate these crucial components into a sustainable sector-enhancing strategy (Selaledi *et al*., 2021a; Marescotti *et al*., 2020). In this study, we evaluate the interactions presented by different insect-based feed attributes to bring out the preferred scenarios to accommodate the aforementioned policy concerns of commercialization, livestock welfare and environmental issues for a sustainable livestock sub-sector and emerging insect industry (FAO, 2017).

Overcoming social barriers associated with some insect-based products is pertinent in ensuring successful adoption and sustainability of the sector. Within SSA, farmers have traditionally harvested insects to supplement livestock diet particularly for the growth of chicken (Dao *et al*., 2019; Pomalégni *et al*., 2018; Sebatta *et al*., 2018). In Kenya, farmers have demonstrated increased willingness to incorporate insects into their livestock production systems (Chia et al., 2020; Waithanji *et al*., 2019). This is probably attributed to indigenous knowledge of the various communities that have observed chicken picking up insects at all life stages and eating them voluntarily, which indicates that they are evolutionarily adapted to insects as a natural part of their diet (Bovera *et al*., 2015; Lin et al., 2014). Furthermore, the traditional practice of consuming edible insects like termites and crickets in different regions in Kenya has favored farmers' readiness to also use them for feed (Kinyuru *et al*., 2018; Ayieko *et al*., 2010). Therefore, it seems reasonable to consider the inclusion of insect proteins as raw material to be used in commercial feed manufacturing and to develop intensive farming systems for these insects. Insects are a rich source of protein (40-60 percent), essential amino acids and fat (Van Broekhoven *et al*., 2015; De Marco *et al*., 2015; Makkar *et al*., 2014) and several experimental trials published to date have expressed both nutritional and health benefits of feeding insect-based feed to broiler and layer chickens (Makkar *et al*., 2014). These studies revealed high total tract amino acids digestibility (over 90 percent) and lower feed intake as compared to control diet with soya bean meal indicating an improved feed conversion (FCR) (Makkar *et al*., 2014). Cognizant of this and the need to conserve biodiversity (Selaledi *et al*., 2021b), this study highlighted the understanding of farmers' creativity and potential to innovate using indigenous knowledge to overcome the protein gap experienced as hindrance to poultry production but also consider their purchase behavior that drives their preferences for commercial insect-based feeds. Specifically, using the choice experiment (CE) method, this study analyzed farmers' preferences for the inclusion of the BSF larvae protein in commercial chicken feed in Kenya. Okello *et al*. (2021) points that in addition to majority of the farmers willing to use insect-based feed, they also demand the products based on specific features of the feed. This means that farmers purchase goods by considering various components and not the entire good as a whole, hence it would be paramount to identify and quantify these features. Therefore, this study quantified farmers' willingness to pay (WTP) for specific insect-based feed attributes, identified in a consultative process with various stakeholders in the chicken value-chain.

Understanding farmers' preferences is critical to forestall product failure for insect-based feed and the sustainability challenges that often characterize top-down non-consultative development processes (Gasco *et al*., 2019). Although there are some recent studies on farmers' acceptance and WTP for insect-based feed in Benin and Kenya (Chia *et al*., 2020; Pomalegni *et al*., 2018) as well as consumers' acceptance of insect-based feed chicken meat in Germany (Altmann *et al*., 2019), studies on the WTP for insect-based commercial chicken feed attributes are scarce. This analysis sought to fill this gap.

Considering that the insect-based feed value chain is an emerging sector in SSA, this study aims to make three contributions to the sustainability of insect-based products. First, the findings contribute to the national discourse on effective and appropriate legislation necessary to facilitate insect farming for protein and commercialization of insect-based products, which depend on availability and generation of evidence-based data to inform policy (KEBS, 2017). Second, the study accounts for preference heterogeneity by applying the random parameter logit to also control for unobserved correlation presented by repeated choice tasks by individual farmers. This allows for efficient estimation of the value (premium or discount) placed by the farmers on the identified attributes to inform the design of insect-based feed market. Lastly, the study further generates welfare estimates for different chicken production systems based on selected market-driven attributes. Through the estimates, we identify the most preferred policy scenarios to guide the implementation procedure for insect-based feed.

The remainder of the paper is organized as follows: section two provides the methods applied in the study, while results are presented and discussed in section three. The paper concludes with a discussion of possible policy interventions.

4.2 Materials and methods

4.2.1 Choice experiment design

The CE process involved three key steps as described in CE literature review of literature to identify potential attributes of IBF; validation of the attributes and their levels through expert consultations and focus group discussions (FGDs) with farmers and; use of statistical procedures to combine various attributes to generate feed bundles/packages (Greiner et al., 2014; Scarpa et al., 2013; Hensher and Rose, 2009). The experts consulted included a local feed miller, representative from the Association of Kenya Feed Manufacturers (AKEFEMA) and livestock extension officer.

Once a list of attributes was developed from in-depth literature review, the stakeholders were involved through face-to-face interviews to verify the validity of each attribute. In line with the suggestion by Greiner et al. (2014), three FGDs were conducted with ten chicken farmers who were representative of different age groups, gender and income categories in each session, to understand the contextual relevance of the attributes and their levels. The aim of the rigorous consultative procedure was to identify compulsory and optional attributes. The compulsory features are non-tradeable and their inclusion in the policy design is part of building farmers' confidence that the new feed is not only for commercialization but takes a holistic approach by aligning with environmental and institutional goals for the sustainability of the feed industry. Four compulsory attributes were identified.

First, it was envisaged that *decentralization* of quality regulatory institutions to county and sub-county levels would ease access to the feed and ensure regular inspection of quality and safety aspects in different market outlets. Currently, KEBS has six regional offices in a country with 47 counties limiting its ability to regularly perform inspections. Liaising with county government to set up county offices will ensure regular inspection and compliance with stipulated standards. Second, in line with the Animal Foodstuffs Act (Cap 345) enforcement of *strict penalties* on individuals who default on quality and other standards through monetary fines, prosecution and confiscation of business licenses was deemed necessary to prevent adulteration of feeds and thus, protect the safety of chicken as well as consumers from hazardous substances (Republic of Kenya, 2012b).

It was noted in the FGDs that farmers were keen on introduction of hefty fines on defaulters instead of prosecution due to the lengthy nature of court proceedings, which might have adverse economic effect on the feed millers/sellers and by extension impede farmers' business progress. Use of *technology-based standards and quality verification* mechanisms that are accessible to all farmers was identified as another mandatory feature. Considering that counterfeit IBF may penetrate the market, it was suggested that verification codes that are compatible with mobile phones would ensure instant traceability in the supply chain and the purchase of authentic IBF. Finally, *partnership* among the farmers, public and private sector contributes significantly to the implementation of policy interventions based on the ingredients and formulation process of IBF. This would reduce overlapping roles and minimize delays that come with standards specification of novel ingredients among the stakeholders.

The optional attributes are those that typically go into the CE design and they allow farmers' flexibility on what levels they desire to be incorporated in the feed design and distribution. Badar et al. (2015) noted that the optional attributes allow consumers to identify and examine the product prior to initiating a purchase. The authors classify these attributes as search and marketing features. In this study, the search attributes included the final form of the feed, protein source and color of the feed, while the marketing features considered were labelling and price (Table 7).

The inclusion of the *feed form* as an attribute in this study was meant to provide insights on farmers' preference based on their experience in feeding diverse breeds of chicken. According to the KEBS (2017), milled insect products can be presented in three main forms including mash, pellets, or crumbs. Pelleting of feed reduces wastage and increases feed intake by birds (Abdollahi et al., 2013). Processing of the crumble diet involves pelleting the ingredients before crushing them to a consistency coarser than the mash (Jafarnejad et al., 2010) whereas the mash is finely ground so that the birds cannot easily separate out the ingredients. However, Biasato et al. (2018) and Sena et al. (2013) noted high feed efficiency and faster growth among birds reared on pellets.

Appropriate *labelling* of products is an important marketing aspect that positively drives consumers' purchasing behavior for the products' existing and new attributes (Bronnmann and Asche, 2017). While Popoff et al. (2017) noted that retailers are reluctant to disclose the type of insects used in livestock feeds due to potential negative attitudes by some consumers, Van Huis (2020) and KEBS (2017), argue that clear labelling of the insect-type on chicken feed is crucial in reducing uncertainties and informing farmers' purchasing decision. Specifically, the KEBS (2017) stipulates that the IBF packaging label should include the name and class of the insect product, insect species, form of processing, and type of substrate used. This study sought to understand whether chicken farmers would prefer disclosure or non-disclosure of insect type on the feed labels.

The *protein source* determines nutritional value of feeds. Moreover, the choice of a particular source of protein to include in the feed depends on individual farmers' attitudes. Even though most farmers in Kenya are aware of the high nutritional value of chicken naturally fed on insects (Chia et al., 2020; Waithanji et al., 2019), other factors such as cases of allergic reactions, disgust and phobia affect farmers' preference for insects as feed (Kornher et al., 2019; Lombardi et al., 2019; Onwezen et al., 2019) may prohibit wide adoption of commercial IBF. Several sources of insect proteins are recommended by the KEBS (2017) among them the BSF larvae, adult crickets, housefly larvae, mealworm larvae and pupae, adult termites and adult or nymph cockroach. This study included two levels of the protein source: exclusive use of BSF in feed, or BSF mixed with SFM. Furthermore, studies like those of Dabbou et al. (2018) and Cullere et al. (2016) have established that partial substitution of conventional protein with insect protein leads to optimal chicken growth.

The *color* of feed depends on the ingredients used and due consideration must be given to whether the resultant color will be appealing to chicken as well as farmers. While the use of synthetic dyes to enhance color is recommended, a deviation from the typical appearance should be critically evaluated as this could have an implication on the quality (Infonet, 2018). Given farmers' experience in chicken-feeding practices, the inclusion of two levels of color: dark and light, were considered appropriate in this study.

Considering that production or improvement of any feed requires resources, it is rationally expected that end users must pay a price premium to compensate for the production costs and some mark-up as business incentive. Therefore, the *price attribute* provides a basis for estimating trade-offs for other IBF attributes. Further, El Benni et al. (2019) observed that price is directly proportional to food quality and safety. Following Bronnmann and Hoffmann (2018), the average market price per kilogram of chicken feed was computed as the average from three local feed retail shops in Kiambu Township. The price of the 70-kg bag of broiler feed was used as for estimating the average price because this feed is also available in pellets and also broiler production is more common among smallholder farmers due to the short production cycle of broiler chicken. This average price, which was Kshs 44 at the time of the survey, was used as the base price level.

Following the standard practice in CE studies (for instance, Otieno and Ogutu, 2020; Bronnmann and Hoffmann, 2018; Pascucci and de-Magistris, 2013), two other price levels set at 45 percent above and below the base level, to account for differentials in farmers' income and price premiums.

Table 7: Description of optional attributes included in the choice experiment design

IBF attributes	Description of attributes	Levels of attributes
Feed form	The physical structure of the feed	Pellets; crumble; mash
Labelling	Labelling of the feeds to indicate that it contains BSF	Yes; no
Protein source	Indication of the protein type included in the feed	BSF only; BSF mixed with SFM
Color	The color of the feed	Dark; light
Price	The price of one kilogram of the feed (Kshs)	24; 44; 64

Note: 100 Kenyan shillings (Kshs) was equivalent to 1 USD at the time of the survey.
Source: Survey Data (2020).

Following Scarpa et al. (2013), the CE design was done using a two-stage process in Ngene statistical software. First, a fractional orthogonal design was generated and used to collect preliminary data from a pilot survey of 42 farmers. The data from the preliminary survey was analyzed to obtain prior coefficients that were subsequently used to generate an efficient design. An efficient design is seen through the D-efficient value and is a design that allows estimation of parameters with low standard errors on a minimum sample size necessary to achieve a certain degree of estimation accuracy (Bliemer and Rose, 2010; Scarpa and Rose, 2008). Kessels et al. (2006) notes that compared to other optimal designs like the A-, G- and V- designs, the D-efficient design is preferred because they generate precise estimates and predictions of the distribution of attributes and often accompany the design softwares like NGENE for the stated reasons. The syntax used to execute these designs are shown in Appendix 1. The efficient design resulted in 24 paired choice sets that were systematically blocked into six profiles. Through blocking, the detrimental effect on data quality that comes with task complexity is reduced (Hensher, 2006). The CE design obtained had a high D-efficiency measure of 83 percent and utility balance, B-estimate of 81 percent. According to Kessels et al. (2011), this confirms the presence of D-optimality which means that there is no dominance by any alternative in the choice sets.

Each choice situation contained two alternative types of feed (IBF type A or type B). In line with the completeness axiom of choice, an opt-out option (neither IBF type A nor B) was included as the third alternative to accommodate farmers who would not wish to choose between the feed types offered, or those whose preferred combinations may not have been fully captured by the design (Greiner et al., 2014). Inclusion of the opt-out option is known to reduce the over-estimation of the WTP values that is sometimes reported in comparative studies between CE and CVM (Danyliv et al., 2012; Ryan and Watson, 2009; Van der Pol et al., 2008). Overall, our CE design alternatives conform to the optimal dimensions suggested by Hensher (2006) and Caussade et al. (2005): four to six attributes with two or three levels and providing a maximum of four alternatives in each choice task.

A pretest of the CE choice cards and survey questionnaire on a sample of 15 farmers proved that the exercise was not complex to the respondents. An example of a choice set presented to the farmers is illustrated in Appendix 2.

4.2.2 Estimation strategy

Following Hensher and Greene (2003) and, McFadden and Train (2000) the study applied random parameter logit (RPL) model in the analysis of CE data since it accounts for preference heterogeneity. The RPL fits within the RUT framework mentioned in Chapter 2. Furthermore, the RPL allows for heterogeneity by allowing the model coefficients of the observed variables to vary randomly over the farmers. This flexibility allows for approximate representation of any substitution pattern exhibited by the data and eliminates the restrictive independence of irrelevant alternatives which is characteristic of alternative models like the multinomial logit (MNL) (Train, 2000). The utility function (*U*) is made up of observed/systematic and unobserved components. The systematic component (*V*) is the portion of the product that relates to the attributes of interest to the analyst while the variations in the choices made by the farmers combined with other measurement errors are captured in the unobserved (random) component (ε) of the utility function.

Following Train (2002) and Revelt and Train (1998), the RPL formulation of the utility function of the n^{th} farmer for a particular alternative *j* in choice situation *t* is expressed as follows:

$$U_{nj} = \beta_n' X_{nj} + \varepsilon_{nj} \tag{3}$$

where X_{nj} is the attribute vector of alternative j and β_n is the unobserved vector of the corresponding coefficient assigned by individual n and varies among farmers with a density function $f(\beta_n|\theta)$ whereby θ is the parameter vector of the distribution. The random component is independent and identically distributed (*iid*) over alternatives and thus permits estimation of the probability that farmer *n* chooses alternative *j* in a given choice set. The choice probability of the random parameter logit is as follows:

$$P_n(\theta) = \int S_n(\beta_n) f(\beta_n|\theta) d\beta_n \tag{4}$$

where $f(\beta|\theta)$ is the density function of β which is described by parameters θ. The objective of the RPL is to estimate the θ using the log-likelihood function because the choice probability from Equation (4) does not have a closed mathematical form therefore should be estimated numerically. The log-likelihood function is given as follows:

$$LL(\theta) = \sum_n \ln P_n(\theta) \tag{5}$$

Following the standard RPL practice, simulation method was used to approximate the probability. A total of 200 Halton simulation draws were used over randomly selected values of β_n. The Halton draws are simulations that help in numerical estimation of the integral of the open mathematical form in Equation (5) with the least simulation error for the parameters to be estimated (Train, 1998). The simulated probability of *n*'s sequence of choices is:

$$SP_n(\theta) = \left(\frac{1}{R}\right) \sum_{r=1}^{R} S_n\left(\beta_n^{r|\theta}\right) \tag{6}$$

where R represents the 200 Halton draws, $\beta_n^{r|\theta}$ is the r^{th} draw from $f(\beta_n|\theta)$. The estimated parameters are those that maximize the simulated log-likelihood (SLL) function which is estimated as:

$$SLL(\theta) = \sum_n ln\left(SP_n(\theta)\right) \tag{7}$$

Following Hanemann (1984), the WTP for BSF attributes (*k)* were computed as ratios of the estimated coefficient of each attribute k (β_k) and the price attribute (β_p) as shown in Equation (8). The negative sign ensures compliance with the rationally expected inverse relation between price and quantity in the conventional law of demand.

$$WTP_k = -\left(\frac{\beta_k}{\beta_p}\right) \tag{8}$$

The results of the CE were further used to measure the compensating surplus (CS) to generate IBF policy scenarios for targeted policy intervention. The CS measures the change in income that would make the farmer indifferent between the initial and subsequent situations based on the assumption that the farmer has the right to initial utility level (Othman et al., 2004; Hanemann, 1984). The income change is an indication of the farmers' WTP for an improved feed that is expected in the IBF. Following Morrison et al. (1999), the CS was estimated using Equation (9):

$$CS = -\frac{1}{\beta_p}(Vo - V1) \tag{9}$$

where β_p is the coefficient of the marginal utility of income while Vo and $V1$ represent the indirect unobservable utility before and after the introduction of the IBF.

4.2.3 Data sources and sampling methods

A multi-stage sampling technique was employed to identify the respondents. In the first stage, three sub-counties namely: Kiambu Township, Ruiru and Thika (Figure 1) were purposively selected from a total of 12 sub-counties in the county due to their high intensity of chicken production and relative proximity to shopping centres. In the second stage, a simple random sampling procedure was applied to select two wards in each of the three selected sub-counties. The selected wards were Ndumberi and Riabai in Kiambu Township, Gatong'ora and Mwihoko in Ruiru, and Gatuanyaga and Thika Township in Thika.

Following the recommendations of Orme (2010) on sample size determination for choice-based research, a minimum sample of 300 farmers was required. Therefore, the final sampling stage employed a simple random technique to whereby 50 farmers were selected in each ward from a sampling frame of smallholder chicken farmers that was provided by the sub-county government extension agents using the lottery method of simple random sampling. The sampling frame comprised of 150 to 200 smallholder farmers in each sampled ward. Fifteen extra respondents from Kiambu Township were included in the sample to account for potential non-response. Data was collected through face-to-face interviews using a semi-structured questionnaire in farm-household survey. The CE section of the questionnaire was implemented in two steps: first, an introductory session was conducted, where farmers were provided with information about the novel feed and were reminded to mimic their buying behavior in a real market situation, when choosing their most preferred alternative.

The importance of making truthful choices to limit non-attendance to certain attributes was emphasized. Subsequently, each farmer was presented with four hypothetical choice scenarios and after careful evaluation of the options, they were asked to choose their most preferred feed type in each choice set. Based on Greiner et al. (2014), each farmer responded to a one profile out of the six with each profile containing four choice tasks. Each task contained three alternatives with the first two containing insect-based feed package with differing attribute combinations while the third alternative being the opt out option as earlier described. The profiles were randomly assigned to the farmers and the study ensured that each farmer responded to only one to reduce task complexity while also ensuring that all profiles had an equal number of responses by the end of the survey exercise.

The survey questionnaire also contained sections on the household socio-demographics, chicken resource endowments and institutional support services. The survey was implemented using computer-assisted personal interviewing open data kit (ODK) software and uploaded on tablets.

The CE data was analyzed using the NLOGIT software version 4. The eventual sample size dropped to 314 after one questionnaire was removed from analysis due to incomplete information.

4.3 Results and discussion

4.3.1 Socio-economic characteristics of chicken producers

A summary of some socio-demographic features of chicken-producing households in Kiambu County is presented in Table 9. More than three-quarters of the households were male-headed with an average age of 50 years, an indication that chicken production is dominated by male middle-aged farmers. Based on the findings of Chia et al. (2020), older farmers are willing to pay for IBF owing to their experience which informs their understanding of the challenges presented by high cost of feed. On the average, farmers had 12 years of formal education implying that most of them had attained a secondary school level of education and could therefore evaluate the attributes and the different choice sets presented to them regarding commercial IBF.

The average monthly household income which was an aggregation of off-farm and on-farm monthly income, was slightly more than Kshs 57,000, which is almost ten times the national minimum wage (Kshs 6,736.30) (Republic of Kenya, 2019b). The high income is expected to positively influence farmers' likelihood and willingness to pay for improved innovations like IBF. This is in line with the findings of Toma et al. (2018) who reported that higher incomes among farmers increased the probability of their uptake of innovative technologies; if their attitudes permit in the case of IBF. Majority of the farmers reported engaging in off-farm activities, which complemented their household income. Since insect-based products are currently associated with high production costs (Sogari et al., 2019), supplementary sources of incomes are necessary in offsetting such expenses.

Three-quarters of the farmers confirmed that they usually sell their chicken. After computing income from the sale of eggs and chicken meat the study computed the percentage share of this income to overall household income. On average, chicken production contributes almost 10 percent of total household income. Even though this is slightly less than the share reported by Okeno et al. (2012) of 17 percent, according to Muriithi and Matz (2015), market participation is associated with higher income hence in this case, commercialization of chicken production is expected to contribute to the use of the improved feed.

Membership to poultry groups was low at 13 percent possibly due to the collapse of some poultry organizations resulting from abandonment of poultry production due to costly feeds (Ssepuuya et al., 2019). In this study, farmers reported that the main role of groups was feed production while post- chicken production activities like marketing were solely managed by the farmer. Low group membership by chicken farmers is common and has been reported elsewhere. For instance, Kiprop et al. (2020) noted that about 73 percent of farmers did not belong to farmer groups, yet groups provide an efficient platform for lobbying and advocating for efficient production (Abdul-Rahaman and Abdulai, 2018) which would be pertinent in ensuring low feed costs.

Nearly a quarter of the farmers cited having received agricultural training pertaining to livestock production hence could better manage different aspects of their livestock. Based on local knowledge and individual observations, most farmers were aware of chicken feeding on various types of insects as an essential source of nutrients. This is explained by the fact that insects form part of the natural diet for free range chicken and chicken can be seen scavenging outdoors for insects among other diets like vegetables. Almost all farmers were willing to use IBF in their chicken production, an indication that farmers are receptive to innovations that are expected to improve their livelihoods.

Table 8: Characteristics of chicken-producing households in Kiambu County, Kenya

Variables	Statistic (n = 314)
Average age of household head (years)	50 (12.05)
Average years of schooling	12 (3.01)
Average household income per month (Kshs)*	57,750 (24,296)
Gender of household head (percent male)	77.39
Off-farm income source (percent yes)	80.89
Commercial chicken production (percent yes)	75.48
Share of chicken income in total income (percent)	8.95
Membership to poultry group (percent yes)	13.38
Awareness of chicken feeding on insects (percent yes)	61.78
Willing to use BSF- based feed (percent yes)	93.32
Sources of information on use of BSF as chicken feed	
Fellow farmers	34.52
Own experience/culture	30.58
Extension officers	14.48
Icipe	17.11
University exhibitions	1.32
Agricultural trade fairs	1.32
Other sources	0.677

Note: *100 Kenyan shillings (Kshs) was equivalent to 1 USD at the time of the survey. Standard deviations for continuous variables are presented in parentheses.
Source: Survey Data (2020).

Peer learning among farmers was the main source of information on the use of BSF larvae in chicken feed, followed by individual experience. This finding is consistent with that of Ipara et al. (2021) and Shams and Fard (2017) who reported that farmers with experience on new innovations share similar information with each other. The popularity of farmer-to-farmer method of information transfer can be attributed to the limited financial resources or lack of public extension services, forcing farmers to individually pay for extension services. Furthermore, Sebatta et al. (2018) observed that farmers' awareness and knowledge of the nutritional role of insects in chicken diet is based on own observations in free-range extensive production systems. Research institutions such as the *icipe* and extension agents were also reported to have played a role in the dissemination of information regarding the use of BSF larvae in chicken feed. This finding could be explained by Chia et al. (2020) findings that the practice of using BSF larvae in commercial feeds is an emerging concept, which still requires more information dissemination by relevant stakeholders including agricultural and university exhibitions.

4.3.2 Farmers' willingness to pay estimates for insect-based feed attributes

The RPL syntax used to derive preference coefficients and WTP values for the attributes are provided in Appendix 4. The RPL estimates of the WTP for commercial BSF based chicken feed are presented in Table 10. All variables were statistically significant at the 1 percent level ($\rho < 0.0001$). The RPL model was highly significant (ρ -value < 0.0001) and exhibited a good explanatory power with *pseudo-*R^2 of 0.37, which fits within the recommended range for discrete choice models (Scarpa et al., 2003; Louviere et al., 2000). Further, the RPL model shows an improvement from the starting log-likelihood value of -956.51 in the multinomial logit (MNL) model to -869.76.

Chicken producers had a positive and significant preference for IBF that was either pelleted or mashed, mixed with conventional protein sources, distinctly labelled, that contained insects and that was dark in color. The statistically significant and negative sign of the price coefficient indicates that a lower price level is preferred and further permits the computation of trade-offs between IBF attributes and money. The statistically significant standard deviations for pellets, labelling and mixed protein sources show that farmers have heterogeneous preferences for these attributes (Llagostera et al., 2019).

Table 9: Random parameter logit estimates for insect-based feed attributes

Variable	**Coefficient**	***ρ* -value**
Pellets	4.300 (0.550)	0.000***
Mash	3.687 (0.550)	0.000***
Label	1.978 (0.188)	0.000***
Mixed	0.739 (0.183)	0.001***
Dark	0.435 (0.103)	0.000***
Price	-0.013 (0.003)	0.000***
Standard deviation of parameter distributions		
*sd*Pellets	1.316 (0.410)	0.001***
*sd*Mash	0.600 (0.944)	0.532
*sd*Label	0.746 (0.258)	0.004**
*sd*Mixed	2.189 (0.231)	0.000***
*sd*Dark	0.327 (0.349)	0.357
Log-likelihood		-869.79
Adjusted *Pseudo*-R^2		0.3669
Chi-square (ρ -value)		1020.13 (0.000)
n (respondents)		314
n (choices)		1256

Note: starting MNL *Pseudo*-R^2 = 0.0145; log-likelihood = -956.51. ** and *** denote statistical significance at 5 percent and 1 percent levels, respectively. Standard errors are in parentheses.
Source: Survey Data (2020).

Farmers had a higher preference for pelleted feed than its mashed counterpart. Further probing revealed that even though pellets are expensive, they reduce wastage because they can be easily collected when scattered in the chicken cages as opposed to mashed feed, which is often swept off when cleaning chicken coops. This finding corroborates those of other studies that have recommended the use of pellets in feed processing because chicken spend less time and energy yet obtain more nutrients when fed on pellets (Abdollahi et al., 2019). Nonetheless, the significant preference for mashed feed could be due to farmers' familiarity with this form, which is currently the prevalent form of feed for all chicken breeds. It was also noted in the FGDs that potential difficulty for chicks to digest pellets makes some farmers to use mashed feed. However, der Poel et al. (2020) observed that the physical form of feed can be resized to meet the preferences of farmers.

As expected, farmers had a positive preference for labelled feed. Farmers consider labels as informative in understanding the changes in feed components and guiding their purchasing decisions. Besides the stipulated guidelines by the KEBS (2017), farmers are interested in labels explicitly showing the existence of BSF to build their trust in the products, and this could be in the form of a special logo. The finding conforms to those of Van Huis (2020) and Pascucci and de-Magistris (2013) who noted the importance of labels in communicating nutritional contents and in enabling traceability of safety and quality aspects in the IBF industry.

The significant and positive preference for IBF that is mixed with conventional protein sources such as SFM shows that farmers are apprehensive of using feed that is exclusively made of insects. A plausible explanation for this is based on food novelty and affective factors like the fear of new foods (neophobia) and disgust which play an important role in farmers' decision to experiment the use of insect-based products (Onwezen et al., 2019; Verbeke et al., 2015). This finding suggests that farmers appreciate the role of monitoring and evaluation on programs designed to improve chicken production. Additionally, the practice of combining commercial feeds with green vegetables and supplements like fishmeal to boost growth of chicken (Sebatta et al., 2018) may have informed the preference for mixed feed. The result is similar to the findings of Schiavone et al. (2019) who observed that various combinations of insect meal with conventional proteins is more beneficial for chicken growth and more preferable as opposed to the exclusive use of insect-meal in feeds. Feed that is dark in color was preferred than one that had a light color. This can be explained by the observation in the FGDs that the dark brown color of feed gives the impression that it has more protein. Khosravinia (2007) also found that chicken farmers preferred rich-colored feed compared to plain colored.

Finally, based on Table 11, chicken farmers were willing to pay between Kshs 189 and Kshs 495 for feed in pelleted form; Kshs 151 and Kshs 435 for feed in mashed form; Kshs 99 and Kshs 217 for BSF-based explicitly labelled as containing insects; Kshs 25 and Kshs 93 for feed mixed with SFM as the sources of protein; and Kshs 16 and Kshs 53 for feed that is dark in color. The WTP estimates show that farmers would pay the highest premium of Kshs 342 per kilogram for pelleted feed than the crumbled feed. During the FGDs, farmers expressed high satisfaction with the effect of pelleted feed on their flock in terms of achieving the market weight within the required time.

Table 10: Farmers' WTP estimates for insect-based feed attributes (Kshs)

Attribute	WTP (at 95 percent CI)	ρ –value
Pellets	341.78 (188.6 - 494.5)	0.000***
Mash	293.13 (151.2 - 435.1)	0.000***
Labelled as containing insects	157.94 (99 – 217)	0.000***
BSF mixed with SFM	58.69 (24.7 - 92.7)	0.001***
Dark color	34.53 (16.4 - 52.7)	0.000***

Notes: CI = confidence interval derived from the Delta method. Values in parentheses represent a range of WTP at 95 percent CI. *** denote statistical significance at 1 percent level.
Source: Survey Data (2020).

Mashed feed was the second-most valued attribute. Farmers were willing to pay Kshs 293 per kilogram for mashed feed owing to its popularity as feed for all chicken breeds. They would pay Kshs 160 per kilogram for feed that is labelled as containing insects while color had the lowest WTP value of Kshs 35 per kilogram. The positive values of the WTP for all the feed attributes included in this study indicates that farmers are willing to pay a premium price for the inclusion of BSF to improve chicken feed. Overall, these results are consistent with recent studies such as Chia et al. (2020) who found that chicken producers were willing to pay a premium range of 12 percent to 57 percent for IBF in chicken production.

In terms of internal consistency, the sum of average WTP values for all attributes is lower than the market price of a mature indigenous live chicken (about Kshs 886 compared to Kshs 1000) in the city of Nairobi where most farmers from Kiambu market their chicken. This demonstrates that farmers who opt to use the improved IBF would be able to make profits in their chicken businesses without requiring resources from other enterprises to offset their costs.

4.3.3 Estimation of compensating surplus for insect-based feed scenarios

The compensating surplus (CS) estimates for three policy scenarios representing various combinations of different IBF-attributes; profit-focused farmers (*scenario 1*); environmental sustainability-conscious farmers (*scenario 2*) and; chicken safety and welfare-sensitive farmers (*scenario 3*) were derived and are presented in Table 12.

The results in Table 12 show that *scenario 3*, which includes feed that is pelleted, explicitly labelled as containing insects, mixed with conventional protein and is dark in color has the highest CS estimate (Kshs 592). This can be explained by the findings of Nakimbugwe et al. (2020) that innovative food products will be accompanied by increased consumer demand for safe insect-based products and associated regulations to ensure compliance. In this case, the safety aspect is ensured through the ability to prevent pellets from contamination as opposed to other feed forms such as mash. *Scenario 1*, in which all attributes are similar to those of *scenario 3* except that it includes mashed feed form rather than pellets has the second highest CS of Kshs 544; confirming the desire of profit-focused farmers to spend less on the production costs but still reap more returns. *Scenario 2* with mashed feed, labelled as containing insects, exclusive use of insect protein and light-colored feed had the lowest CS of Kshs 499. This scenario targets farmers who are conscious of the harsh environmental impact of conventional protein sources on natural resources. A closer inspection reveals that the exclusive use of insect protein and light color pull the CS downwards in *scenario 2*.

Table 11: Compensating surplus (CS) for insect-based feed policy scenarios

Scenarios	Attributes								Compensating surplus (in Kshs)
	Pellets	Mash	Labelled	Not labelled	Insects and SFM	Insects only	Dark	Light	
1		✓	✓		✓		✓		544.30Ψ (110.07)
2	✓		✓			✓		✓	499.73 (102.47)
3	✓		✓		✓		✓		592.95 (117.46)

Notes: ✓ indicates presence of an attribute at the non-zero level; Ψ all the CS estimates are statistically significant at 1 percent level; Corresponding standard errors are shown in parentheses.

Evidently, the CS estimates are higher than the actual market price of feed per kilogram. However, it is important to note that these values are not indicative of the need to further increase the prices of already problematic feed prices. On the contrary, the CS estimates are meant to bring to the attention of policy makers and other authorities in the chicken value chain the strategies that are more implementable and acceptable by all stakeholders, by considering the feed production costs, which ultimately have a considerable effect on chicken production costs and farmers' profitability.

4.3.4 Conclusion and policy recommendation

The study used the RPL model to account for preference heterogeneity. The estimates revealed that farmers would be willing to pay premiums for IBF that is: pelleted or mashed in form; exclusively labelled as containing BSF protein for ease of identification; mixed with conventional protein from soybean and fishmeal for optimal chicken performance; and dark in color to signify presence of protein ingredient. Therefore, the design of IBF should incorporate these features to increase its acceptability and consequent adoption once available in the market. Further analysis showed that there is high preference for IBF policy scenarios that are considerate of profit-oriented farmers, environmentally conscious and those sensitive to chicken welfare aspects. The null hypothesis is, therefore, rejected and the study concludes that farmers are willing to pay for IBF attributes.

Several policy implications can be from this study. First, there is need to encourage the production and use of locally fabricated pelleting machines to ease the cost of pelleting. This could be achieved through establishing communication platforms between local artisans and feed millers, through their respective associations, to relay information on recommended pellet sizes, and further assist in developing BSF defatting equipment to ensure efficient grounding and mixing of mashed feed. Second, the importance of labelling as a means of identification and creating trust in quality calls for consultations between quality regulators and insect producers on the appropriate and standard logos to use for IBF, that will differentiate certified insect-based products from other livestock-related inputs. This could be complemented with capacity building for farmers to enhance their technical knowledge on identifying quality insect products in the market.

Third, research institutions could liaise with farmers to expand their research on identifying the optimal proportions of BSF meal combined with soybean and fish meal for competitive chicken growth and performance. Through this approach, farmers would also participate in instant assessment of the benefits of the feed and also partake in relaying valuable feedback to aid in the improvement of policy framework. Fourth, our data revealed that there are differences in the importance of attributes of IBF which can be associated with differences in individual and behavioral preferences. This implies that a “one-size fits all” approach to designing feed formulation strategies ought to be discouraged. Therefore, policy interventions that are targeted at ensuring acceptability of the feed should be participatory and adjusted to the contextual preferences of the relevant community.

CHAPTER FIVE: GENERAL CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

The use of insect protein in commercial livestock feed formulation is an emerging and innovative concept to cushion farmers against the current high prices of feed. This study evaluated farmers' perceptions and preferences for the insect-based feed prior to its commercial launch. This way, farmers reveal their unobserved patterns that influence their purchasing behaviour and they also get the opportunity to design features of the feed that suit their preferences. The study used the principal component analysis (PCA) and ordinary least squares (OLS) to generate four perception indices which were subsequently used in the OLS to assess the socio-economic and institutional factors that influence the perceptions. The performance, acceptability, versatility and marketability indices of the feed were the crucial unobserved indicators that inform farmers' decision making for purchasing feed.

For performance, farmers pay particular attention to the quality of the feed with regards to what they can observe when purchasing feed and later monitor as the chicken grows. This component explained the highest variation of (35 percent) meaning that it is the most prioritized characteristic. Farmer characteristics like awareness of chicken feeding on insects for nutritional benefits and access to off-farm income influenced performance of the feed. Acceptability of the feed, which pertains to social norms and customs that surround innovations, explained the second highest variation of 12 percent among the perception indices. When the society accepts the use of insects in feeding chicken then the farmers are more likely to purchase the feed when it is commercially available. This index is particularly important for this study because the use of insects in human food chains is region-specific and probability of acceptance is higher in regions with prior exposure to insect-consumption. Farmers who had prior knowledge of the benefit of insects in chicken nutrition, those with off-farm income sources and those in societal groups considered this index as important plausibly because of access to information that comes with these characteristics.

Looking at the versatility feature of the feed, since farmers rear chicken at different growth stages with different feed requirements at these stages, and also some farmers keep more than one type of livestock, this feature shows that they are concerned on whether the feed can cater for the differences. This allows them to be consistent with their feed purchasing behaviour to help them minimize on any challenges that may be caused by feed source and brand variations. Educated farmers and those with wealth assets preferred this feature of insect-based feed. Marketability of chicken products reared on insect-based feed was considered a priority by educated farmers and those aware of the nutritional benefits of insects as they are well-informed on the positive effects of insects on the end-products because chicken naturally scavenge on insects when allowed to free-range. These last two indices explained the least variations of nine percent and seven percent for versatility and marketability, respectively.

In order to evaluate farmers' willingness to pay (WTP) for insect-based feed attributes, this study used the choice experiment design method to elicit farmers' preferred attribute combinations and the random parameter logit (RPL) model to analyse WTP estimates. Farmers were willing to pay premiums for four attributes, that is, the feed form (pellets or mash), labels indicating the feed contains protein, insect feed mixed with soy bean and fish meal proteins and dark feed color. The feed form could either be pellets or mash whereby the former reduces feed wastage and ensures efficient feeding by reducing energy spent on feeding by the chicken, while the latter is the conventional and cheaper form because it doesn’t require special pelleting machines. The labelled feed informs the farmer of the feed that contains insect protein to help in decision-making while the protein mix with conventional sources allows the farmer a chance to monitor and evaluate the effect of partial substitution of conventional protein on their chicken before they can be confident of a complete replacement. The dark feed color is an indication that the feed contains protein which is essential for chicken bone formation.

The study further estimated the compensating surplus of various policy regimes for insect-based feed using different attribute combinations. The highest compensating surplus (CS) was for the chicken welfare-sensitive policy scenario (Kshs 593) for feed packaged as pelleted, labelled mixed with soybean and fishmeal and dark in color meaning that most of the farmers are cognizant of the need to rear chicken in humane conditions and this will subsequently attract more income from like-minded consumers. A profit-oriented scenario revealed a CS of Kshs 544 for mashed, labelled, mixed with conventional protein and dark-colored insect-based feed. This scenario is conducive for farmers who want to maximize profits and reduce costs. Finally, environmentally conscious farmers are willing to pay a CS of Kshs 500 for pelleted feed that is also labelled, purely insect protein and light in color. These policy scenarios align with the mandates of various national and global policies as mentioned earlier. Of importance is for the governments to identify the prioritized scenario and aim at ensuring that an ideal environment is created to realize the respective attributes.

5.2 Conclusion

The main objective of this thesis was to examine farmers' perceptions and preferences for commercial insect-based feed in Kiambu County, Kenya. Cross-sectional survey data from 314 predominantly chicken-rearing households was collected for analysis. The study revealed that there are important observed and unobserved factors that will influence farmers' decision making when purchasing insect-based commercial chicken feed. Regarding the unobserved factors, this study has revealed that it is indeed important for researchers to study farmers' perceptions to elicit their hidden behavior that plays a critical role in the adoption of innovations. The farmer-based information indicators provide a good starting point for policy interventions to ensure successful uptake of the feed. The positive willingness to pay estimates means that farmers would be willing to purchase the feed when designed to meet the discussed features.

The study reveals that farmers are indeed ready for changes in the composition of commercial feed with the prospect of improved quality for improved income. This means that commercial chicken production in Kenya is important to farmers' livelihood and the findings established here could transform the chicken sub-sector. Furthermore, the unique approach employed by this study through the inclusion of farmers in all design stages of the new feed will increase farmers' confidence in purchasing insect-based feed to promote chicken production which will consequently contribute to rural development.

Even though the production volume of the feed is still quite low because of few players in mass insect production, major opportunities exist in the regulatory environment for both chicken production and the emerging insect value chain. This study identified key (mandatory) attributes that would guide the implementation framework of using insects in chicken feed formulation. Considering that these attributes are not tradeable in the market like the optional features and farmers have little control over their implementation, it is upon the relevant regulatory bodies like Kenya Bureau of Standards to oversee their enforcement to increase farmers' confidence in the feed and consequently in the actions of the respective bodies that also aim to transform the mentioned sub-sectors. Furthermore, farmers' preference for welfare-sensitive production requires regulators to rethink chicken production systems and identify mechanisms through which farmers can be equipped to align with those preferences.

5.3 Recommendations

Farmers have expressed their preferences and the immediate changes that they would like to see take place to create a trustworthy environment for insect-based commercial chicken feed production. This calls for collaborations between various stakeholders to develop and update the existing guidelines to incorporate the identified design features to ensure a sustainable environment for the feed production. Research organizations, feed manufacturers through their umbrella association and insect farmers could further benefit from the findings established here by engaging farmers to actualize their most preferred production system and how this system can translate into monetary benefits to the farmers.

5.4 Suggestions for further research

Considering the multi-stakeholder environment in which feed formulation takes place, the study recommends further studies to understand the risk factors and preferences within a wider geographical coverage to generate more insights on behavioral preferences of different actors besides farmers; this would ensure wider acceptability and sustainability of IBF in the chicken value chain. Studies from evidence-based on-farm trials from farmers with different resource endowments providing information on the feasibility of integrating IBF in chicken production would be relevant in complementing the information presented in this study. Since this study revealed the importance of commercial chicken production, the national government could also play an active role of implementing national surveys to map the chicken value chain to update its records of the contribution of chicken to the economy. Outcomes from such activities will assist in identifying challenges faced in other poultry production systems like the indigenous chicken and how insect-based feed can be tackle those hurdles.

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Appendix 1: Household Interview Questionnaire

Perceptions and Preferences for Commercial Insect-Based Feed in Kiambu County, Kenya

Household Survey Questionnaire, February, 2020

Respondent

In this survey, household head, spouse or older family members above 18 years old, familiar with and involved in decision-making on household livelihood/chicken production activities will be interviewed. **Only households that rear chicken will be interviewed**.

Purpose of this survey

This survey aims to get come insights on chicken production, use of production inputs and acceptance of chicken feed that is integrated with the black soldier fly larvae (BSFL). Your voluntary participation in answering questions on these issues is highly appreciated. Your responses together with those from over 300 chicken farmers in other parts of Kiambu County will be analyzed and the findings will be used to inform policy makers on better strategies for improving chicken production in the area. All the information obtained will be treated with utmost confidentiality and will only be used for the purpose of the survey. This interview will take approximately 45 minutes to complete.

SECTION A: GENERAL INFORMATION

Cover sheet	Response
Enumerator's name	
Date of interview (dd-mm-yyyy)	
Sub-County	
Ward	
Sub-Location	
Village	
Household number	

SECTION B: CHICKEN INFORMATION

1. Do you keep chicken? 1. Yes 0. No
   If No in Q. 1, why did you stop keeping chicken? (*Multiple responses allowed*)
   i) Lack of market
   ii) Chicken death due to disease
   iii) Chicken death due to pests
   iv) High cost of feed
   v) High cost of other inputs
   vi) Theft
   vii) Lack of finance
   viii) Lack of space
   ix) Others (specify)
   (*After answering this question, thank the respondent and terminate the interview*)

2. If Yes in Q. 1, which chicken type do you keep? Please fill the table below:

Chicken type	Breeds kept	Numbers kept	Number of years practiced	Production system used: 1.Free range 2.Caged system 3.Both caged and free range system	Importance in terms of income	Importance in terms of food security	Importance in terms of societal/cultural aspect
Layers							
Broilers							
Turkeys							
Ducks							
Quails							
Guinea fowls							
	Importance code: 1. Not important 2. Important 3. Very important						

3. Is the household head a member of a chicken producer group/association? 1. Yes 0. No
4. If NO in Q. 3, why?
   (1 = I do not have time for groups 2= I cannot afford membership dues 3 = There are no groups in my area 4 = Other (specify)…………)
5. If YES in Q. 3, please fill the table below:

Name of the poultry producer group/association (List all)	Structure of the group: 1=Formal, 0=Informal	Objectives of the group: 1=Marketing of produce, 2=Input acquisition, 3=Offers credit, 4=Others (specify)	Agreement that the group achieves its objectives: 1=Strongly disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly agree	Frequency of group meeetings: 1=Weekly, 2=Every fortnight, 3=Monthly, 4=Annually, 5=Others

6. Are you keeping poultry under any contractual agreements? 1. Yes 0. No
7. If YES to Q. 6, please fill the table below:

Main contractor (*Choose one*): 1=Kenchic, 2=Trader, 3=Hotel/restaurant, 4=Schools, 5=Hospitals, 6=Other (specify)	Who are the other contractors? 1=Kenchic, 2=Traders, 3=Hotel/restaurant, 4=Schools, 5=Hospitals, 6=Other (specify)	Type of arrangement with the main contractor: 1=Formal, 2=Informal	Roles of the main contractor (*Choose more than one*): 1=Inputs provision, 2=Purchasing of the produce, 3=Provision of veterinary services, 4=Provision of credit, 5=Provision of training 6=other (specify)

8. Have you received any training on poultry husbandry in the last 12 months? 1. Yes 0. No
9. IF YES in Q. 8, how many times were you trained in the last 12 months?
10. Who trained you on poultry husbandry? (*Multiple answers allowed*)
    a) Livestock extension officer
    b) Input supplier
    c) Mass media
    d) Agricultural trade fairs/exhibitions
    e) Poultry contractor
    f) ICIPE
    g) Others (specify)

i) Input Information

11. Are you a member of any savings and credit institution/organization group? 1. Yes 0. No
12. If YES in Q. 11, please specify the type of the savings and credit group (*Multiple answers allowed*):
    a)SACCO b)Table banking c)Merry-go-round d)Formal bank e)Mobile money
13. Can you access credit from any of the sources if you needed it? 1. Yes 0. No
14. Have you received credit over the last 12 months? 1. Yes 0. No
15. If YES in Q. 14, please fill the table below:

Source	Amount received	Amount received Vs amount applied for: 1=25 percent; 2=50 percent; 3=75 percent; 4=100 percent	Use: 1=buy poultry inputs, 2=buy general farm inputs,3=pay school fees, 4=buy assets, 5=buy food 6=expand poultry business	Proportion of loan already repaid: 1=25 percent, 2=50 percent, 3=75 percent, 4=100 percent	Challenges to credit access: 1=lack of collateral, 2=high interest rates, 3=procedural, 4=others
Formal bank					
Microfinance					
SACCO					
Agricultural Finance corporation (AFC)					
Community groups					
Relatives/friends					
Poultry contractor					
Mobile money (specify)					

16. If NO to Q. 14, what was the main reason for not receiving credit?
    a) Lack of collateral
    b) No need for a loan
    c) Lack of credit source
    d) High interest rate
    e) Others (specify)
17. In your opinion, do you agree that the following are constraints that you face as a farmer? (*Tick where appropriate*)

Constraints	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Lack of markets					
Low poultry prices					
Diseases					
Expensive poultry feed					
Expensive poultry inputs					
Lack of veterinary services					
Competition from imports					
Lack of extension services					

Lack of credit					

18. Who provides most of the labor in the poultry production enterprise? 0. Family 1. Paid 2. Both
19. If Paid labor:
    i) How many laborers do you employ?....................
    ii) Under what arrangement is the paid labor organized?
        a) Permanent basis b) Casual basis c) Both permanent and casual basis
20. Do you use purchased inputs eg. Feeds, feed supplements and additives, antibiotics, drinking water among others in poultry production? 1. Yes 0. No

    If Yes in Q. 20 which of the following do you purchase and what are the challenges faced in accessing them? Please fill the table below:

Purchased inputs	**Input name**	**Where input is purchased (stockist): 1. Retailer 2. Wholesaler 3. Feed miller 4. Fellow farmer 4. Others (specify)**	**Challenges: 1. High prices 2. Not available 3. Late supply 4. Others (specify)**
Feeds			
Feed supplements and additives			
Antibiotics and vaccines			
Drinking water			

21. If No in Q. 20:
    i) What is your main reason for not purchasing feed?
    ii) Where do you source your feed from?

SECTION C: AWARENESS AND PERCEPTIONS OF USE OF BSFL IN FEED

22. Are you aware of the use of insects in poultry feed?

Insect type	**Awareness (1 = aware 2= not aware)**	**Where did you learn about it? 1 = Extension worker 2 = Neighbor/farmer 3= Own experience 4= Mass media 5 = other (specify) ………………….**
Black soldier fly larvae		
Cockroaches		
Termites “kumbekumbe”		
Housefly maggots		
Crickets		
Grasshoppers		

23. I am going to read to you some statements about your feelings on the use of BSFL in feed. Kindly indicate whether you strongly agree, agree, disagree, strongly disagree or if you are in-between these options

Statement	**Strongly agree**	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
The use of BSFL in chicken feed is not any different from conventional feed					
BSFL in chicken feed is more nutritious than conventional feed					
Chicken fed with BSFL chicken feed grow faster					

BSFL in chicken feed is cheaper than conventional feed					
BSFL in chicken feed increases feed intake by chicken					
BSFL in chicken feed is a more sustainable protein source					
BSFL in chicken feed is of low quality compared to conventional feed					
BSFL in chicken feed does not have a bad smell which makes the feed palatable					

24. I am going to read to you some statements about your feelings on the ethics of the use of BSFL in feed. Kindly indicate whether you strongly agree, agree, disagree, strongly disagree or if you are in-between these options

Statement	**Strongly agree**	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
The use of BSFL in chicken feed is not safe for my chicken					
Use of BSFL in chicken feed is against my religious belief					
Use of BSFL in chicken feed is acceptable my culture					
Use of BSFL in chicken feed will increase the price of my chicken					
I don't think my customers will buy chicken that is fed on BSFL in chicken feed					
I am willing to use BSFL in chicken feed in producing chicken					

ii) Output Markets

25. Did you have access to market information during previous season? 1. Yes 0. No
26. IF YES in Q. 25, from which source?
    a)Traders b)Contractors c)Radio/TV d)Fellow farmers e)Others (specify)
27. Who mainly decides on the price of produce?
    a)Me b)We as farmers c)The buyer d)We negotiate e)Others (specify)
28. Kindly give us the quantity of poultry products that you have consumed and sold to the market over the last 6 months. Please fill the table below:

		Broilers	**Layers**	**Turkeys**	**Ducks**	**Quails**	**Guinea Fowls**
Quantity of meat (kg)	Consumed						
	Sold						
	Ksh/kg						
	Value (Ksh)						
Quantity of eggs (trays)	Consumed						
	Sold						
	Ksh/tray						
	Value (Ksh)						

29. What marketing channels do you usually use to sell poultry products? Please fill the table below:

	percent of products: 1=1 percent-25 percent; 2=26 percent-50 percent; 3=51 percent-75 percent
Wholesale	
Retail	
Middlemen	
Contractors	

30. How do you process (slaughter) your poultry?
    a)Home processing b)Slaughterhouse c)Sell without processing d)Others (specify)
31. How do you dispose/ use poultry waste?

Waste type	**Method of disposal (code)**
Poultry droppings/manure	
Offals	
Codes: 1=Use as feed, 2=use as manure, 3=dispose in sewage, 4=dispose by the roadside, 5=sell as feed, 6=sell as manure, 7=sell as human food, 8=Other (specify)	

32. Do you store some poultry manure/waste? 1. Yes 0. No
33. If YES in Q. 32, do you store the poultry manure/waste?
    a) In piles/heap b) In bags c) On the farm d) Others (specify)

SECTION D: ASSETS OWNED BY THE HOUSEHOLD

34. Which of the following assets does this household own? Fill the table below:

Asset Item	**Number owned**	**Estimated value of the asset**
Farm implements: hand hoes, panga, ploughs, etc		
Carts and wheelbarrows		
Spray pumps, irrigation pumps, irrigation pipes		
Water tank, borehole		
Mobile phones, radios, TV		
Bicycle, motorbike, vehicle		
Residential house		
Buildings for rent		
Poultry shed		
Livestock unit		
Land		
Shares and stocks		
Others		

SECTION E: DEMOGRAPHIC CHARACTERISTICS

35. I am going to ask you about the characteristics of you and your household

Question	**Response**
Gender of the household head (1= male, 2= female)	
Age of the household head (Years)	
Marital status (1= single, 2= married, 3= widowed/divorced/separated)	
Years of schooling of the household head	
Number of males in the household	

Number of females in the household	
Number of people who have lived in this household in the last 4 months	

SECTION F: EDUCATION AND EMPLOYMENT

36. I am going to ask you about your household's education and employment:

	Aged below 15 years	**15-35 years**	**36-65 years**	**Above 65 years**
Number of household members				
Labor disaggregation				
Working on-farm daily				
Working off-farm daily				
Working both on and off-farm				
Education (Quality of human capital)				
Completed primary education: Male= Female=				
Completed secondary education: Male= Female=				
Completed tertiary education: Male= Female=				
Completed university education: Male= Female=				
Dropped out of primary: Male= Female=				
Dropped out of secondary: Male Female=				

SECTION G: FARM ENTERPRISE

i. Livestock

37. What type of livestock do you keep on your farm? Please fill the table below:

Livestock	**Breeds kept**	**Numbers kept**	**Number of years practiced**	**Main reason/purpose for engaging in this enterprise: 1.Food 2.Sale 3.Draught 4.Cultural use eg. Dowry payment, status symbol etc5.Manure 6.Store of wealth**	**How initial stock was acquired: 1.Bought 2.Inherited 3.Received as bride price 4.Received as gift 5.Others (specify)**	**Land size allocated for the enterprise-housing, pasture development/grazing etc (acres)**
Cattle						
Sheep						
Goats						

Donkeys						
Bee-keeping (hives)						
Other (specify)						

ii. **Crops**

Three main crops grown	Land size allocated to each crop (acres)	Yield in the last season (kg)	Main purpose for the crop production: 1.Food 2.Sale 3.Both food and sale

38. How did you acquire the land you are currently using? Please fill the table below:

Method of land acquisition	**Land size owned (acres)**	**Tenure system: 1.Private with title deed 2.Private without title deed 3.Communal 4.Others (…)**
Allocated by clan		
Inherited from parents		
Bought		
Rented		
Leased		
Received as a gift from an institution/other people		
Settlement scheme		
Others (specify)		

SECTION H: INCOME ACTIVITIES

39. What are your major sources of income? Please fill the table below:

Income source	**Amount derived**	**Proportion of income derived from it: 1=none, 2=<25 percent, 3=25 percent-50 percent, 4=50 percent-75 percent, 5= >75 percent**	**Number of male adults involved**	**Number of female adults involved**
Poultry				
Crops- (list 3 main ones)				
Livestock- (list 3 main ones apart from poultry)				
Business				
Employment				
Artisan				

SECTION I: FUTURE SCENARIO

40. What other enterprise would you like to engage in or continue in the next 5 years? Please fill the table below:

Enterprise: 1=poultry, 2=livestock, 3=crops, 4=business rent, 5=others (specify)	**Motivation: 1=more profitable, 2=less time-consuming, 3=resource availability, 4=reduced interest rate, 5=less capital required, 6=others (specify)**	**Needed support: 1=capacity building, 2=institutional framework, 3=reduce bureaucracy, 4=infrastructure development, 5=security, 6=reduce taxes, 7=access to credit, 8=others (specify)**

Appendix 2: Example of insect-based feed choice set

IBF attributes	**IBF type A**	**IBF type B**	**Neither A nor B**
Feed form	Pellets	Mash	None
Labelling for IBF	Not labelled	Labelled	None
Protein source	BSF mixed with SFM	BSF only	None
Color	Dark	Light	None
Feed price per Kg (Kshs)	24	64	None
Which ONE would you choose? (*Tick where appropriate*)			

Source: Survey Data (2020).

Appendix 3: Model diagnostics of the MANOVA for multivariate multiple linear regression

Model diagnostic	Statistic	F-value
Wilks' lambda	0.621 ***	5.44
Pillai's trace	0.416 ***	5.01
Lawley-Hotelling trace	0.551 ***	5.86
Roy's largest root	0.426 ***	18.40
Observations (n)	310	
Residual	302	

Notes: ***, ** and * denote statistical significance at the 1 percent, 5 percent and 10 percent levels, respectively.

Source: Survey Data (2020).

Appendix 4: Choice experiment design syntax

a) Orthogonal design

Design

```
;alts=alt1,alt2
;rows=36
;block=6
;orth=sim
;model:
U(alt1)=b0+b1*x1[0,1,2]+b2*x2[0,1]+b3*x3[0,1]+b4*x4[0,1]+b5*x5[0,1,2]/
U(alt2)=b1*x1 +b2*x2 +b3*x3 +b4*x4 +b5*x5$
```

b) Efficient design

```
Design
;alts=alt1,alt2
;rows=24
;block=6
;eff=(mnl,d)
;model:
U(alt1)=b1[0.53]*x1[0,1,2]+b2[1.5]*x2[0,1]+b3[0.94]*x3[0,1]+b4[0.49]*x4[0,1]+b5[-
0.02]*x5[0,1,2]/
U(alt2)=b1*x1 +b2*x2 +b3*x3 +b4*x4 +b5*x5$
```

Appendix 5: Random parameter logit, willingness to pay syntax and compensating surplus syntax

```
Sample; all$
RPLOGIT; Lhs=CHOICE
   ;CHOICES=a,b,c
   ;Rhs =PELLETS,MASH,LABEL,MIXED,DARK,COST
   ;FCN=PELLETS(N),
   MASH(N),
   LABEL(N),
   MIXED(N),
   DARK(N),
   COST(C)
   ;pds=4
   ;halton
   ;pts=200$

WALD; Labels=b1,
   b2,
   b3,
   b4,
   b5,
   b6,
   sd_b1,
   sd_b2,
   sd_b3,
   sd_b4,
   sd_b5,
```

```
    Fix_b6,
    ;start=b
    ;Var=Varb
    ;Fn1=-1*(b1/b6)
    ;Fn2=-1*(b2/b6)
    ;Fn3=-1*(b3/b6)
    ;Fn4=-1*(b4/b6);
    Fn5=-1*(b5/b6)$

WALD; Labels=b1,
            b2,
            b3,
            b4,
            b5,
            b6,
            sd_b1,
            sd_b2,
            sd_b3,
            sd_b4,
            sd_b5,
            Fix_b6
      ;start=b
      ;Var=Varb
      ;Fn1=(-1/b6)*(b1*0+b2*1+b3*1+b4*1+b5*1)
      ;Fn2=(-1/b6)*(b1*1+b2*0+b3*1+b4*0+b5*0)
      ;Fn3=(-1/b6)*(b1*1+b2*0+b3*1+b4*1+b5*1)$
```