EVALUATION OF CONSUMER WILLINGNESS TO PAY FOR CHICKEN EGGS PRODUCED FROM COMMERCIAL BLACK SOLDIER FLY (*Hermatia illucens)* LARVAE BASED FEED IN KIAMBU COUNTY KENYA

COLLETA NABWILE KHAEMBA

A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Master of Science Degree in Agribusiness Management of Egerton University

EGERTON UNIVERSITY

AUGUST, 2023

DECLARATION AND RECOMMENDATION

Declaration

I declare that this thesis is my original work and to the best of my knowledge has not been presented for the award of any degree in this or any other university.

Signature:  Date: 16/02/2023

Colleta Nabwile Khaemba

KM19/14594/18

Recommendation

This thesis has been submitted with our approval as university supervisors.

Signature:  Date: 15/02/2023

Prof. George Owuor, (PhD)

Department of Agricultural Economics and Agribusiness Management,

Egerton University, Njoro (Kenya)

Signature:  Date: 15/02/2023

Dr. Michael Kidoido, (PhD)

Social science and Impact Assessment Unit (SSIAU)

International Centre of Insect Physiology and Ecology (ICIPE)

Duduville Campus, Nairobi (Kenya)

DEDICATION

This thesis is dedicated to God, my parents Gladys and the late Julius Khaemba, my sisters Angeline, Brenda and Daisy and my beautiful daughter Nia, for their unconditional love, encouragement, and endless support.

ACKNOWLEDGEMENTS

First, I thank God for the gift of life, strength, courage, determination, and protection He gave me throughout the research period. I express my gratitude to my supervisors Prof George Owuor and Dr. Michael Kidoido for their extensive knowledge, guidance, support, motivation constructive insights and unconditional interest in my study. I am also thankful for the Department of Agricultural Economics and Agribusiness Management for their endless support.

I am grateful to the Centre of Excellence in Sustainable Agriculture and Agribusiness Management (CESAAM) for offering me a full scholarship to pursue MSc. In Agribusiness Management. I am also grateful to the International Centre of Insect Physiology and Ecology (ICIPE) for giving me an MSc research fellowship through which I was able to complete my thesis.

I am very grateful to my parents, siblings and daughter who have always given me unconditional love and moral support through this period.

I thank my fellow students, especially AGBM class of 2018 and friends for their unfailing support throughout the study. I also thank the enumerators for assisting me during data collection. I am grateful to the consumers who responded to the questions and to everyone who made any contribution towards successful completion of this thesis.

ABSTRACT

Poultry production is gaining a wider importance in Kiambu County as a source of food and income generation. The egg productivity and quality are important factors considered by consumers. The production is however insufficient, unsustainable, and constrained by lack of quality feed. There is a drive to use insects for feed, particularly black soldier fly larvae as an alternative in commercial poultry feed to remedy this situation. However, important information to support the use of insects in commercial poultry feed is scanty. The general objective of this study was to contribute to a diversified commercialized black soldier fly-based chicken feed for egg production as a way of improving consumer welfare. Specific objectives of this study were: to determine consumers' perception of eggs derived from black soldier fly larvae-based feed; consumers' socioeconomic and institutional factors significantly affecting the perceptions and finally to evaluate the willingness to pay for eggs derived from black soldier fly larvae-based feed. The study used a descriptive research design. Multistage sampling was used to select 200 consumers who were interviewed using a pretested semi-structured questionnaire. Data was analyzed using Exploratory Factor Analysis (EFA), binary logistic regression and Random Parameter Logistic (RPL) regression. Results indicate that consumers positively perceive eggs produced from commercial insect-based feed. Perception of these eggs was influenced by gender, awareness of insects as feed, off-farm income, household income, nature of buying place, and access to credit with positive coefficients of 0.78, 1.41, 1.27, 0.91, 0.85, 1.0, and 0.31 respectively. The RPL was used to analyze conjoint analysis data and estimated the relative importance of main attributes that affect consumer preferences for eggs. The RPL analysis indicated heterogenous and high preference for attributes of eggs produced from insect-based feed as all attributes were significant at 0.00. The results show that consumers prefer golden yellow yolk eggs and eggs derived from black soldier fly larvae-based feed. It was also found that price was the most important attribute in determining consumer preferences. The results from this study instill hope in sustainable use of insects in poultry feed through promoting the consumption of insect-based food products based on the insights from the desirable egg attributes.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASTGS	Agricultural Sector Transformation and Growth Strategy
CA	Conjoint Analysis
CBCA	Choice Based Conjoint Analysis
EU	European Union
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GoK	Government of Kenya
ICIPE	International Centre of Insect Physiology and Ecology
KALRO	Kenya Agricultural and Livestock Research Organization
KEBS	Kenya Bureau of Standards
KNBS	Kenya national Bureau of Statistics
MoLD	Ministry of Livestock Development
MT	Metric Tonnes
SDG	Sustainable Development Goals
SPS	Sanitary and Phytosanitary Standards
SSA	Sub Saharan Africa
WTP	Willingness to Pay

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Developing countries, Kenya included are faced with increasing demand for animal-based protein rich food due to a growing population and rising income (FAO, 2017a). This has an impact on the agricultural sector which plays a vital role in the Kenyan economy. The sector contributes 26% of the GDP and another 27% of GDP indirectly through linkages with other sectors (World Bank, 2015). It employs about 75% of the labour force (KNBS, 2018). The sector is faced with the challenge of sustainably increasing production of animal proteins in the wake of climate change, environmental degradation, land, and water scarcity (FAO, 2015). The current animal protein sources are meat, milk and eggs whose supply is relatively limited and unsustainable resulting from the high cost of production (GOK, 2013). The Kenya Vision 2030 and the Agricultural Sector and Transformation Strategy (ASTGS) have emphasized the need to use modern technologies to improve production in livestock to meet population needs (GOK, 2007, GOK, 2019a).

The livestock sector accounts for about 12% of the national GDP. The value of marketed livestock and livestock products increased by 8.3% to KSh 146.8 billion during the year under review (KNBS, 2018). Therefore, development in the livestock sector has a positive impact on poverty levels as it boosts income and improves food security for Kenyans in both formal and informal sector (GOK, 2007; KIPPRA, 2017; Omiti & Okuthe, 2009). Among the important subsectors within the Kenyan livestock sector is the poultry subsector accounting for about 30% of the livestock sector's GDP (Netherlands African Business Council, 2015). The national estimated population of poultry is 29 million with 68% of them being free-range chicken (KNBS, 2018). In Kenya, Kiambu county has the largest number of poultry farms, with most intensive commercial farms located in the county (KNBS, 2013). It also has the largest egg market in Kenya, Wangige market.

The poultry subsector contributes to incomes in rural and urban households and improves nutrition by the provision of meat and eggs as there is a growing demand for poultry products. Annual poultry meat production is estimated at 605,000MT while egg production is 1,716 million which is valued at KES 10.3billion (GOK, 2019b). Hence, the sector's significance cannot be overlooked as production is increasing to meet the growing demand for its products. Chicken eggs have high levels of micronutrients, carbohydrates, fats and

fatty acids, protein, amino acids, vitamins, and minerals (Rondoni *et al*., 2020). They have a high nutritional content and are associated with high satiety (Holt *et al*., 1995). Characteristics such as nutrition density and versatility of eggs to be consumed for all meals has created a popularity among consumers and this has led to commercialization and increased production and marketing. According to Guyonnet (2012), egg consumption is on the rise as it has positive perception as a snack and as food.

Generally, poultry production in Kenya is estimated to increase over the years slowly but steadily from 44 million in 2016 to about 57 million heads in 2020 (GOK, 2019c). Despite the growth, there is still a shortfall to meet the demand for eggs. The slow growth is attributed to the following challenges: inadequate quality feed, high cost of available feed due to feed materials used, inadequate market information and lack of adequate capital to invest in the farms (Shaw, *et al.* 2019). In the recent past, the government and other stakeholders in the livestock sector have increased their efforts in promoting the production of high-value livestock thus increasing competition in the livestock sector. These efforts have also contributed to the growth in poultry production. For instance, KALRO non-ruminant research project works on improved local (kienyeji) chicken and conducts training for farmers to increase their production. The improved local chicken is dual purpose and are both for producing eggs and meat. The project realized increased production in households that adopted the technology (KALRO, 2015).

In Kenya, the increasing rate of urbanization has seen a deviation from traditional lifestyles. This has resulted in higher incomes and consequently consumers preferences have also changed. This has a direct impact on food access and availability (Alphonce & Alfnes, 2017). Consumers' have become increasingly knowledgeable and make informed decisions based on the information available to them. Eggs are seen as an alternative protein source to red meat which is expensive and has been linked to the rise in colorectal cancer. Growth in egg consumption is accredited to the perception of it being a healthy alternative (Van Den Brandt, 2019). This has seen traders importing large quantities of eggs from Uganda to meet the growing demand (GOK, 2019a). According to FAO (2017a) egg consumption in Kenya is expected to grow at 4.15% annually through 2050.

Animal feed production is mainly dependent on plant-based and fish-based feeds. The feeds use conventional protein sources (soybean meal, cottonseed cake, fishmeal, and fish oil) which account for 60-70% of production costs (Ravindran, 2013; Veldkamp *et al.,* 2012).

However, the production of conventional protein is faced with challenges of land scarcity, poor quality and high cost of ingredients as well as concentrates, unavailability of local sources of vitamins, amino acids, macro- and micro-nutrients, climate change and food-feed fuel competition (Van Huis, *et al.* 2015). This implies that an increase in the prices of conventional plant-based and fish-based proteins results in an increase in the prices of feed and this has a direct impact on poultry production and prices for the products (Van Huis *et al*., 2015).

Research in alternative protein sources to increase productivity has been prompted by the increasing cost of production. Studies have shown insects as a potential solution to replace soybeans and fish meal in animal feed production (Alemu *et al*., 2015). The potential for use of insects as both food and feed is seen as a viable alternative due to its advantages of more protein and micronutrients such as iron and vitamins (Duinkerken *et al.,* 2012). However, despite the wide research, use of insects as feed is not yet fully exploited as challenges arise as it evolves. Key challenges include perception of products that include insects as an ingredient in their production and the marketplace acceptance (Kostecka *et al.,* 2017). There may also be a change in intrinsic and extrinsic egg attributes due to the shift to sustainable methods of production (Barnkob *et al.,* 2020).

The use of insect as feed has been tested and cited as a high source of protein and lowers cost of feed (Van Huis *et al*., 2013). Insects have previously been fed directly to poultry and fish and stakeholders have provided insights on how best to incorporate them into the feed (Van Huis *et al*., 2015). There have been several insect species that have been tested and found to have higher protein content than conventional protein. The most common species are the black soldier fly (*Hermetia illucens*) and the common fly (*Musca domestica*), the yellow mealworm beetle (Tenebrio Molitor) and the alphitobium (*Alphitobius diaperinus),* the domestic cricket (*Acheta domesticus*), the tropical cricket (*Gryllodes sigillatus*), silkworm (*Bombyx mori*) and the silent cricket (*Gryllus assimilis)* (Duinkerken *et al*., 2012; Van Huis *et al*., 2015).

Among the rising technologies, black soldier fly larvae have emerged as a promising protein source offering the additional benefits of being cost effective, all year production and use in waste management (Diener *et al*., 2009; Dortmans *et al.,* 2017). Black soldier fly larvae can be reared on a wide array of wastes enabling the reduction of wastes disposed of by households, requires a small space for production and reduces the carbon footprint

(PROteINSECT, 2016). Black soldier fly larvae are rich in dry matter proteins at 40%-45%, amino acids, carbohydrates, fats at 3035%, minerals and some essential vitamins at 5% (Dortmans *et al*., 2017). These attributes are important as feed supplement to poultry. Therefore, eggs produced from chicken fed on black soldier fly larvae-based feed are expected to be of better nutritional quality than those from chicken fed on conventional feeds. However, there are some potential risks associated with the use of insects as feed such as perception and market acceptance (Duinkerken *et al*., 2012). These challenges are not adequately researched, and further studies are needed.

Consumers have shown preference for insects as food and feed. In Kenya, termites, black ants, grasshoppers, and crickets are part of traditional diet in rural communities (Kinyuru *et al*., 2016) Insects are also naturally a part of free-range chicken diets as they have been found to be a protein rich source (Zotte *et al.,* 2019). However, chicken that are reared commercially depend on manufactured feeds. This has led to research on insect-based feed and has yielded positive impacts and is set to transition to smallholder farmers for use. Thus, analyzing the use of insect-based feed in poultry production is important as it can provide interventions that target lower costs of feed and higher quality products.

1.2 Statement of the Problem

Kiambu County largely depends on agriculture as a source of economic and nutritional empowerment. The residents mainly depend on milk and eggs for animal-based poultry supply. Eggs are viewed as an easy to access source of protein. However, the sources are insufficient and expensive due to the high cost of poultry feeds, unavailability of raw materials locally for the production coupled with adulteration of fish meal results in poor quality eggs that are sold in the market. This has resulted in lack of access to sufficient and nutritional animal-based proteins by residents in the County. Hence, insect-based feed is viewed as an alternative to providing a reliable source of quality feed locally and increases the production and nutritional content of eggs. ICIPE and other stakeholders carry out research to broaden knowledge and improve agricultural production hence enhance food security and contribute to growth of economies. Insect-based protein technology has been introduced but, consumer acceptability of products acquired with the use of insect-based feeds has not been adequately studied. For instance, consumer preference and willingness to pay for eggs produced from chicken fed on insect-based feed have not yet been established. This study, therefore, aimed to fill the gap in the literature by establishing willingness to pay

for eggs derived from black soldier fly larvae-based feed and preference of the eggs among consumers.

1.3 General Objective

To contribute to a diversified commercialized black soldier fly-based chicken feed for egg production as a way of improving consumer welfare.

1.3.1 Specific Objectives

i. To determine the consumers' perception of eggs produced from chicken fed on black soldier fly larvae-based feed.
ii. To analyze socioeconomic and institutional factors affecting consumers' perceptions of eggs produced from chicken fed on black soldier fly larvae-based feed.
iii. To determine consumer willingness to pay for eggs produced with black soldier fly larvae-based feed.

1.4 Research Questions

i. How do consumers perceive eggs produced from black soldier fly larvae-based feed?
ii. What are the socioeconomic and institutional factors that influence the perception of eggs derived from black soldier fly larvae-based feed by consumers?
iii. Are consumers' willing to pay for eggs produced with black soldier fly larvae-based feed?

1.5 Justification of the Study

The food poverty rate in Kiambu County is 23 percent despite it being a predominant agricultural production area (KNBS, 2018). The County has put forward its strategy in its integrated development plan to address the problem through diversification of livestock production to increase food security and increase farmers' incomes. Black soldier fly larvae replacement in poultry feed could be one way of diversifying the poultry feed sector in Kiambu county.

Black soldier fly larvae use in poultry production could contribute to the achievement of Agricultural Sector Transformation and Growth Strategy (ASTGS) objective of achieving increased livestock output through increasing the quality of feed available (GOK, 2019a). Black soldier fly larvae use in poultry production will also help in achieving Sustainable Development Goals (SDG) such as no poverty and zero hunger especially for the poor and vulnerable people. (GOK, 2007). This is through creation of employment opportunities in

farming black soldier fly and increased productivity and availability of poultry products. Furthermore, while assessing the potential of edible insects as food and feed, Rumpold and Schlüter (2013) emphasized the necessity of consumers' acceptance and willingness to pay studies regarding insects as feed.

The findings from this study contribute to knowledge on consumer preference that is important for developing black soldier fly larvae-based feed to be used in poultry and agribusiness development. The study provides important information on the increasing use of insects for feed thus responding to FAO call of addressing animal feed challenge (FAO, 2017b). This can help farmers in decision making on the use of black soldier fly larvae-based feed based in production. Furthermore, findings from this study inform policymakers on designing and implementing policies on the use of insects in commercial poultry feed in the country. This study also provides an insight on consumers' decisions, preference and WTP for eggs derived from chicken fed on black soldier fly larvae-based feed in Kenya, which is currently unavailable.

1.6 Scope and Limitation

This study was carried out in Kabete, Kikuyu and Ruiru sub counties in Kiambu county, Kenya. The study focused on black soldier fly use in poultry feed. It aimed at finding the consumer perception on eggs produced from black soldier fly larvae-based feed, factors significantly affecting willingness to pay for eggs produced from chicken fed on black soldier fly larvae-based feed and to elicit a hypothetical willingness to pay for the eggs. The limitation encountered in this study was the perspective adopted. The study was hypothetical and was restricted to stated preferences. There is also limited knowledge on the adverse effects of prolonged use of black soldier fly-based feed on eggs and consumers.

1.7 Operational Definition of Terms

Choice Based Conjoint Analysis- A 'stated preference' method because it asks people to directly state their preferred choice of goods.

Perception- It is one's own special way of seeing or viewing things (products) or becoming aware of something.

Potential consumer: - is an individual or a household unit that is willing to consume eggs produced from chicken fed on insect-based feed.

Willingness to pay - The desire to give a certain amount of money to acquire a certain product, in this case, the eggs produced from chicken fed on black soldier fly larvae-based feed.

CHAPTER TWO

LITERATURE REVIEW

This chapter discusses the literature on the use of insects as food and feed and the potential benefits of black soldier fly larvae. It also discusses the factors that determine the perception of consumers on the use of insect-based feed in animal feed and identifies gaps within the stated literature. The last section discusses the conceptual framework used in this study.

2.1 Insects as Food and Feed

Insects have been consumed as food (entomophagy) in diets of rural communities around the world for almost 7,000 years (Rumpold & Schlüter, 2013). In Kenya, the most common species are winged termites, black ants, grasshoppers, locusts, and lake flies (Kinyuru *et al.*, 2016). However, the uptake of consumption of insects has been very low as it is faced with the challenge of the disgust factor. Other limiting factors in consumption of insects is that they are seasonal and highly perishable (Van Huis *et al.*, 2013). Despite the limitations, insects are still a potential source of proteins, micronutrients, fats, and vitamins (Van der Camenzuli *et al.*, 2018).

Insects have been used as an additional source of protein to enrich low protein foods such as maize and sorghum to help reduce nutritional deficiency (Kinyuru *et al*., 2009). Termites, sardine, and grain amaranth have been used in formulation for protein rich meals for children and mothers in Mumias subcounty to reduce malnutrition (Konyole *et al*., 2012). The insects are dried and converted to powder or paste form before adding to the flour. The insects can also be consumed directly by frying or boiling. Some of the edible insects have also been fed directly to chicken as they are considered to have high protein content.

Commercialization of insects has however been faced with the challenge of negative perceptions. Food safety issues and the processing nature of transforming insects into protein as food needs to be addressed as this influences consumer acceptability (Rumpold & Schlüter, 2013). Lack of proper documentation of benefits and nutritional contribution of insects as food has also hindered the uptake of commercialization of edible insects. Van Huis *et al*. (2015) highlighted the need of materials on how to conduct sustainable rearing, harvesting, storage and processing to commercialize insects as an alternative source of protein.

Insects are naturally consumed by free range animals and can therefore be easily adapted in their feeds (Dao *et al*., 2019; Sebatta, *et al*., 2018; Ssepuuya *et al*., 2017). Traditionally, insects were consumed by animals and its inclusion in commercially manufactured feed in

modern times is bridging the gap between science and traditional practices (Selaledi *et al.*, 2021). The composition of insects in terms of protein, amino acids, fats, and essential vitamins are superior to those in plant supplements used in feed. Furthermore, their low cost of production and efficient conversion factor make them superior and a promising alternative for use in feed (Veldkamp *et al.,* 2012). Increased population growth and slow growth in production of soybean and fish meal have created a protein deficit problem. Thus, studies have shown there is a need to find a solution and insects have the potential to being a viable alternative (Makkar *et al*., 2014; Van Huis *et al*., 2015).

Several insect species that is; the yellow mealworm, common housefly, cricket, silkworm, locust meals, locusts, crickets, earthworms and grasshoppers and black soldier fly have proven to be viable for feed (Onsongo, 2017; Veldkamp *et al.,* 2012). Agunbiade *et al*. (2007) conducted a study on the inclusion of maggot meal as a replacement for fish meal in cassava product-based layers diet. The study found notable differences in hen-egg day production, shell thickness and shell weight but the changes did not have any harmful effects. The study concluded that maggot meal had no adverse effects on the laying and could be used to replace fish meal in layer diets. Black soldier fly larvae can be used as a replacement for fishmeal in laying chicken and shows significant improvement in hen day egg production. Also, changes in egg weight, yolk colour, egg mass and shell thickness were positively affected by inclusion of black soldier fly in the diets (Al-Qazzaz *et al.*, 2016). Recent studies show that there is improved egg and meat quality on chicken fed on insect-based feed (Mwaniki *et al.*, 2018). However, further research on long-term effects on laying hens and during peak of lay and on resulting egg quality is required (Khan, 2018).

The use of black soldier fly larvae as animal feed has been seriously considered, most importantly for their reduced environmental footprint (Dortmans *et al.*, 2017; Plain & Station, 1977). They can reduce poultry manure mass by 56% and even greater reduction in the nitrogen and phosphorous components (Miranda *et al.,* 2019). According to Maurer *et al*. (2016), in their study on replacement of soybean cake with black soldier fly larvae demonstrated that black soldier fly larvae partially replaced traditional soybean meal and fish meal in diets of growing layers. The study found that it has no adverse effect on the health and metabolic status of layer chicken. However, the study recommended future studies to focus on use of black soldier fly larvae as a potential feed additive and the pricing mechanisms to be used since the insect sector is still not competitive (Maurer *et al*., 2016). Although feeding trials show black soldier fly larvae as a potential substitute for protein,

further studies on the rearing substrate and processing techniques are necessary as some trials have shown negative results on black soldier fly larvae (Makkar *et al*., 2014).

2.2 Black Soldier Fly Larvae

Black soldier fly (*Hermetia illucens*) is a fly (*Diptera*) of the Stratomyidae family. It is a native insect from the tropics, sub tropics and warm temperate regions of the American continent. Black soldier fly is currently present in most parts of the world which are between latitude 40 south and 45 north (Caruso *et al*., 2014). The larvae of the black soldier fly have been studied and found as a possible protein replacement and has an additional advantage of bioconversion of large amounts of organic waste into protein biomass (Diener *et al.*, 2009; Dortmans *et al.*, 2017). It is also considered due to its short life span, low disease vulnerability and its use of minimal space during rearing.

Black soldier fly has an added advantage compared to other insects in that it can deal with unfavorable environmental conditions including food shortage and oxygen deficiency (Dortmans *et al.*, 2017). It can be reared on a variety of substrates that undergo treatment first and are then fed to the larvae. The substrates are essentially biowastes which include organic waste, food & restaurant waste, market waste, spent grains, slaughterhouse waste, poultry manure, pig manure human feces and feces sludge (Dortmans *et al*., 2017). The availability of rearing substrates locally makes it ideal for both small scale and large-scale production (Nyakeri *et al.*, 2017). The adult black soldier fly does not require particular care as it relies on food stored during its larval stage and is less likely to be carrier of diseases (Diclaro & Kaufman, 2009; Wang & Shalomi, 2017).

2.3 Issues in the Use of Insects as Feed

Studies have emphasized the importance of consumer concerns over products produced using insect-based feed (Joel, 2018; Onsongo *et al*., 2017; Rumpold & Schlüter, 2013). This is because of the shift in consideration of the use of insects in poultry production. The consumer being the end destination of products is expected to have preferences and this determines the success of a newly developed product. Consumer concerns mainly arise from the ability of the new product to meet their dietary needs and have no adverse effects on their health. The differences in concerns by consumers arises due to differences in their characteristics (Lancaster, 1966).

The use of black soldier fly larvae as a sustainable protein source is however accompanied by several challenges. Lack of comprehensive legislation, unclear laws, and omission in policy

documents such as Kenya Bureau of Standards (KEBS) do not have specific standards on use of insects as feed. Lack of proper regulatory framework has slowed down commercialization of insect farming. KEBS have documented procedures and guidelines on use of black soldier fly as animal feed but there is still a gap to be filled in terms of adequate information availed to actors in the value chain (KEBS, 2017). According to Sanitary and Phytosanitary Standards (SPS) of KEBS, insects are viewed as contaminants in food and feed (Halloran *et al*., 2015). Previous studies on consumer acceptance to use insects have shown the need for regulations to safeguard the production of insect-based feed (Dörper *et al.*, 2021; Sogari *et al.*, 2019). This implies that consumer views play a vital role in policy formulation, and it affects the underlying design.

Insects are used informally in diets of indigenous chicken. Concerns on presence of harmful contaminants such as heavy metals, toxins produced by or accumulated by the insect, pesticide residue and veterinary drug residue depending on the substrate used to rear black soldier fly larvae have been raised (Van der Camenzuli *et al*., 2018). This has attracted social stigma on entomophagy and use of insects as feed regarding insects that consume waste. Insect allergens are also an issue during rearing process (Rumpold & Schlüter, 2013). The shelf life of the insects has also been questioned as not many processors are able to have proper storage to hold for a longer capacity due to the processing techniques used (Rumpold & Schlüter, 2013).

2.4 Use of Black Soldier Fly Larvae in Waste Management

Africa as a middle- and low-income continent is faced with the challenge of waste management. It produces a large amount of solid waste, 56% of which is organic material (UNEP, 2018). Rapid population growth and urbanization coupled with unreliable waste management systems and poor planning systems exacerbate the problem (Wilson, 2015). Continued uncontrolled dumping of waste increases the release of methane which is a harmful greenhouse gas (GHG) that fuels global warming (UNEP, 2018). As a result, there has been a shift to find alternatives for waste management. Black soldier fly larvae has emerged as a viable waste management option that converts biowaste to protein for animal feed and has by products that can be used as fertilizer (Miranda *et al*., 2019). Black soldier fly larvae are known to convert and sanitize biodegradable waste which includes farm manure and vegetable and animal food waste (Li *et al*., 2011). The waste if left in the environment would release GHG and increased global warming. Black soldier fly larvae can reduce waste by 50%. They rapidly convert waste reducing the smell from decomposing waste (Makkar *et*

al., 2014). Black soldier fly larvae can be used to control the population of the common housefly (Musca domestica) which is a disease vector and thereby improving human and animal health. Biodiesel production from black soldier fly larvae has also become an area of interest as a sustainable renewable fuel. However, its production cost is the main hinderance because it uses feedstock (crop oil such as sunflower oil, soybean oil) (Li *et al*., 2011).

2.5 Consumer Perception on Eggs Produced from Chicken Fed on Black Soldier Fly Larvae based Feed

Perception is an opinion on something. It involves sensory systems that include vision, hearing, smell, and touch. It is not only limited to the passive receipt of these signals but also shaped by attention, memory, expectation, and learning. In this study perception will indicate how potential buyers of eggs derived from black soldier fly-based feed perceive the eggs. Consumer perception underlies the success of a new product in the market. However, all stakeholders in the animal sector should contribute to control and consumption of safe and quality feed. The participation of stakeholders during new product development is key in responsible research (Silva *et al*., 2019).

Communication among stakeholders is key as it helps information flow from all concerned parties. Communication strategies are aimed at getting feedback from consumers as this helps in developing products that consumers perceive as suitable. Consumer perceptions are very complex and often change when making purchase decisions. Their feedback is important as markets are demand driven. Demand is driven up by positive perception of the commodity.

The feasibility of a vibrant egg industry is dependent on consumers who demand commodities and are willing to pay for them. Demand for the eggs is dependent on habits, attitudes, beliefs, intrinsic and extrinsic factors. Intrinsic factors include physical characteristics such as size, weight, and quality while extrinsic factors include price, packaging, and images for advertisement. Quality of the product contributes to beliefs and therefore purchasing choices (Jaafar, 2011). Furthermore, consumers knowledge on sustainability of a product has been found to influence its perception (Laureati *et al*., 2013). Understanding these factors and how they influence consumption ensures that both demand and supply links are equally satisfied.

Veldkamp *et al.* (2012) did a feasibility study on use of insect as a protein source in pig and poultry among stakeholders in Netherlands. Using the stated preference approach, results showed that use of insects is technically feasible, and it is a promising link to fill the growing

demand for protein. The results indicated that large scale production could possibly reduce the cost of production because of use of cheap bio-waste products and use of high productive protein rich insects. It concluded that stakeholder participation is key to learning perceptions on use of inset as feed.

Based on the study by Verbeke *et al.* (2015), attitudes towards insect-based feed were generally positive. Consumer attitude includes trust, familiarity, and perceived economic situation. Generally, stakeholders who were familiar with insect-based feeds defined the products well as they were more aware of the risks and benefits associated. Hence, education on products derived from insect-based feed is necessary to help build the knowledge gap and make consumers feel confident about them.

2.5.1 Determinants of Consumer Perception

Studies that have focused on consumer perception regarding the use of insects in animal feed are scarce (Verbeke *et al.*, 2015). Joel (2018) in research conducted to understand preference and Willingness to Pay (WTP) for poultry meat derived from insects in Kenya. The study found that consumers were willing to pay a premium for poultry meat produced from insect-based feeds. The study also revealed that consumers' socioeconomic characteristics such as income, household size and purchase outlets had an impact on consumers' WTP and preference. This result was further confirmed by a study conducted on Spanish consumers that indicated that respondents were willing to purchase insect fed fish at a premium price (Lagostera *et al*., (2019). Domingues *et al.* (2020) showed wide acceptance of using insects to feed fish, poultry, and pigs among Brazilian consumers. found that consumers were least accepting of the use of insects to feed cattle. Similarly, a study conducted by Spartano and Grasso (2021) reported that UK consumers had a positive attitude towards eggs from insect-fed hens. The study suggested price, animal and environmental welfare were key drivers of acceptance of the eggs.

Apart from the aforementioned determinants, other studies have shown information on nutritional benefits and positive environmental benefits have an impact on determining acceptance by consumers (Laureati *et al*., 2016; Naranjo-Guevara *et al*., 2021; Roma *et al*., 2020). Several studies have shown price, taste as determinants to consumer perception. According to Bazoche and Poret (2020), French consumers intention to choose insect-based products was the same as conventional products at the same price. Contrary to this finding,

Ankamah-Yeboah *et al.* (2018) found that Danish consumers intention to consume insect-fed fish was positively expressed only when there was a price reduction,

2.6 Willingness to Pay

Willingness to pay is a measure of the maximum price which a consumer will pay for a product or service. It is dependent on the attributes of the product, institutional and the socio-economic characteristics of the consumer (Adekunle *et al.*, 2016). The concept WTP arises due to an innovation and the ever-changing market dynamics of consumer or producer driven demands. The WTP price premium is the difference between the WTP for a product that has an attractive feature and one that does not (Alfnes & Rickertsen, 2011). Consumers aim at maximizing their utility subject to a budget line and therefore choose the product that gives them the highest utility. Consumers elicit different WTP for a particular good, this difference can show how information of the good or service is perceived in the target population (Kimenju & De Groote, 2008). Therefore, WTP not only gives an insight into consumption patterns but also assesses the economic feasibility of the product or service.

From literature, revealed preference and stated preference methods are the two main methods for valuation of non-market goods/services and newly introduced goods/services ex-ante. Revealed preference methods rely on consumer purchasing habits to econometrically infer WTP for a nonmarket good. Stated preference methods involve asking individuals about how they value the good in question. Revealed preference methods usually rely on observed behavior and are limited by estimating use values only while stated preference can estimate both use and nonuse values (Lancaster, 1966). Stated preference methods include contingent valuation, choice experiments and conjoint analysis which this study used.

Consumer studies on value added products have shown that they are willing to pay premium prices for them. Kimenju and De Groote (2008) conducted a study on WTP for genetically modified (GM) food in Kenya. The study focused on WTP for yellow maize and bio-fortified maize. They found that consumers in urban areas had a higher acceptance of GM maize meal and were willing to purchase the maize meal at similar prices to their preferred maize meal brand. However, very few consumers were willing to buy yellow maize at the same price as white maize. The survey also found that contrary to expectation, positive benefit perceptions on GM maize were not expressed. The consumers largely focused on the negative perceptions such as health risks and ethics in the GM sector.

Verbeke *et al*. (2015) conducted a study on determinants of willingness to accept the use of insects in animal feed among consumers and other stakeholders in Belgium. The study used an ordered logit and found that acceptance towards the use of insects was generally positive. Respondents were particularly drawn to the reduction in dependency on imported protein and reduction of organic waste and therefore benefit perceptions outweighed the risks. The current study is similar as it assesses perception towards insect-based feed and the factors influencing WTP. The current study aims to fill the knowledge gap on WTP for eggs produced from chicken fed on black soldier fly larvae-based feed by focusing on consumers perception of insect as feed in Kenya.

2.6.1 Elicitation methods for willingness to pay.

There are several ways to elicit someone's willingness to pay. The formats that tend to be used are open-ended approaches in which the respondent settles on the item and the highest price he or she would be ready to pay for a good or service. This strategy could garner a lot of negative feedback and few supportive comments. If the respondent is uninterested, as there may be many zero or no responses. A major drawback of this method is respondents may believe that the responses will be used to generate the price for the good or service (Alberini & Cooper, 2000).

An additional method for obtaining WTP for a product is to use a bidding game style. This technique involves asking the responder if they would be prepared to spend up to a certain amount before eliciting their maximum WTP (Randall *et al*., 1974). This method has the disadvantage that once the respondents note the pattern of the questioning, they tend to give strategic answers. To eliminate such bias, the use of discrete choice questions has been recommended. This study recognizes that some products from insect-based feeds may be present in the market, however it seeks to recognize a shift in the commercialization of insect-based poultry feed. It is in this line that this study anchors analysis of preferences for eggs produced from chicken fed on commercial insect-based feeds as a non-market evaluation approach. The stated preference methods assess the value of the good by using an individual's stated behavior in a hypothetical setting. These methods are advantageous in such a way that the researcher can control relationships between attributes, which permits mapping of utility functions with technologies different from existing ones, as well as being able to include existing and/or proposed choice alternatives (Hearne *et al*., 2004). The main stated preference approaches are conjoint analysis (CA) and contingent valuation method (CVM). The CA approach, specifically Choice Based Conjoint Analysis (CBCA) has been

chosen in this study over CVM because of its consistency with valuation of non-market goods/services. This means that in CBCA, respondents choose from alternative bundle attributes rather than ranking them. CBCA is an appropriate approach in this study as it examines individual preferences for egg attributes. CBCA is designed to determine the trade-offs among product attributes. One of the most fundamental concepts of conjoint analysis is that it measures utilities. A utility is a subjective judgement of preference that is unique to each respondent. The approach asks people their WTP to obtain a specified good based on the utility from its attributes. A product does not provide but rather the attributes of the product give rise to utility (Lancaster, 1966). This implies that a consumers' utility is subject to attributes of a good. The model assumes that alternative product concepts can be defined as a series of specific levels of a common set of attributes. These aspects have made CBCA an accepted approach to study behavioural response of households and consumers in different fields such as environment, market research, health economics and econometrics (Louviere *et al*., 2000).

Within CBCA, respondents are asked to assess several options described by a set of attributes and choose that one which best matches their preferences. This is repeated as many times as choice situations are presented to the respondent. Besides its consistency with RUT, CBCA provides a possibility of obtaining more information from a relatively small sample size and the possibility to test for internal consistency. Additionally, it provides for implicit elicitation of WTP among the respondents (Hanley *et al*., 2001).

2.7 Desired Attributes in Eggs Produced from Insect-Based Feed

Choice-based conjoint analysis decisions relating to the selection of attributes, the levels of attributes, alternatives and choice tasks that are explained based on qualitative approaches such as literature reviews and focus group discussions and expert input and an iterative process of the orthogonal design (Greiner, 2014). This study inquired from literature review sources that have used insects as an alternative protein source to come up with known and observable egg attributes.

Kenya Bureau of Standards (KEBS) identifies black soldier fly larvae as an ingredient that may be used in the production of insect-based products (KEBS, 2017). Black soldier fly larvae have desired properties for use in animal feed (Makkar *et al*., 2014) that has led *icipe* to research into its mass production and use in insect-based poultry feed. Concerns over food safety of entomophagy continue to dominate the debate on acceptance of the use of insects as

food and feed in Kenya. Even though the ICIPE has conducted mass production of black soldier fly (Shumo *et al.*, 2019), proper guidelines should be adhered to by other stakeholders. For this reason, KEBS formulated guidelines on the production and recommended use of dried insects in animal feeds (KEBS, 2020).

Studies have shown that the use of black soldier fly larvae in egg production in layers comprises the compulsory egg attributes, the literature suggests other key attributes may influence the perception of these eggs (Al-Qazzaz *et al.,* 2016). By incorporating black soldier fly larvae as a protein source, new characteristics in eggs have been noted such as changes in yolk colour and size. Currently there are no specific standards that specify the grading for chicken eggs in Africa (Chukuwuka *et al*.,2011). It therefore becomes of paramount importance to elicit from consumers the desired attributes that they would want in eggs as they are the end consumers. Some studies have reported that consumers have shown a preference for products that are insect-based as they are assumed to be more nutritious (Alemu *et al*., 2017; Verbeke *et al*., 2015). In Kenya, an egg is estimated to be at least Ksh. 12. Literature suggests that insect-based feed is 19 percent cheaper than conventional feed (Onsongo *et al.,* 2018) and this price change is expected to be experienced in poultry products.

Consumers have the discretion on the final yolk colour in the eggs, where some may opt for it to be golden yellow while others prefer pale yellow colour. In a study by Al-Qazzaz *et al*. (2016), it was found that yolk colour was influenced by the inclusion of black soldier fly larvae. Chicken fed on feed that constituted higher levels of black soldier fly laid eggs that had a brighter yellow yolk (Al-Qazzaz *et al*., 2016).

Previous studies have shown that egg size is affected by the inclusion of black soldier fly larvae. Marono *et al.* (2017) reported there were differences in egg size that might be attributed to the digestibility of black soldier fly larvae by chicken. It, therefore, becomes important to investigate egg consumers as the final consumers on this attribute of the egg size.

Generally, feeds constitute the conventional proteins that consumers are familiar with. These are well-known proteins that are also used as food by consumers. Therefore, deviation from the typical protein should be seriously considered as this could imply market acceptance (Kostecka *et al.,* 2017). Van Huis *et al.* (2013) reported neophobia (avoidance of unfamiliar

products) for insect-based food products. Table 1 below gives the specification of the attributes discussed above.

The framework used is guided by the various studies that have conducted CBCA.

2.7 Theoretical Framework

The theory underpinning determination of the factors that influence willingness to pay among consumers is random utility theory.

2.7.1 Random Utility Theory

The random utility theory (RUT) provides an analytical basis for CBCA data. This theory has a similar incline with Lancaster's economic theory of value and neoclassical economics which presume that a person will derive utility from the characteristics of a good/service rather than directly from the good/service (Lancaster, 1966; Manski, 1977). Therefore, the consumers' preferences for egg attributes are defined over bundles of attributes and demand for the eggs is derived demand. An underlying assumption is that the attributes are objectively measured and fully known. The Lancaster theory is included in this study and therefore does not violate the neoclassical assumption. In this case, the marginal rate of substitution (MRS) describes the relation between two attributes. The RUT therefore allows researchers to elicit preferences for complex multidimensional goods/services, from which models of preferences can be estimated (Hall *et al*., 2003). The assumption is that individual agents make choices to maximize their utility (random utility maximization hypothesis).

Each consumer is assumed to be a rational decision maker who maximizes utility considering the choices available. Given a consumer i in making a choice considering exclusive alternatives of choice set I of egg characteristics, the selection may differ in line with the decision maker. The consumer i assigns each alternative j in his choice set of perceived utility U^i_j and selects the characteristics that maximizes his utility. The utility assigned to each choice alternative depends on several observable attributes of the alternative itself and the consumer who is the decision maker.

$$U_j^i = U^i X_j^i \quad (1)$$

In equation 1, $U_j{}^i$is the expected utility and $X_j{}^i$ is a vector of attributes relative to alternative j and to decision maker i, utility is not known with certainty and a random variable must usually represent it. The probability that the consumer selects alternative j conditional of his choice set I^i is given by:

$$P^i\left(\frac{j}{I^i}\right) = P^i\left(U_j^i > U_k^i\right) \ \forall k \neq j \ k \in I^i \quad (2)$$

The perceived utility $U_j{}^i$ in equation 2 can be expressed as sum of two terms: a systematic utility and a random residual. Systematic utility $V_j{}^i$ is the mean of all consumers having the same sense of choice as the decision maker i. $\varepsilon_j{}^i$ captures the combined effects of the different factors that bring up uncertainty in choice modeling, it is expressed in equation 3 as:

$$U_j^i = V_j^i + \varepsilon_j^i \qquad \forall j \in I^i \quad (3)$$

With $V_j^i = E\left(U_j^i\right)$ then $E\left(V_j^i\right) = V_j^i$, $var\left(V_j^i\right) = 0$ and $E\left(\varepsilon_j^i\right) = 0$, $var\left(U_j^i\right) = \sigma_{ij}^2$ and yields

$$P^i\left(\frac{j}{I^i}\right) = Prob\left(V_j^i - V_k^i > \varepsilon_k^i - \varepsilon_j^i\right) \qquad \forall\, k \neq j \qquad k \in I^i \quad (4)$$

Where P^i is the choice probability. Equation 4 indicates the probability of consumers selecting alternative j and it implies that the preference of a given alternative depends on the systematic utilities of all competing alternatives and on the law of joint probability of random residuals ε_j. A consumer would probably choose the option that provides a higher utility among the alternatives.

2.8 Conceptual Framework

In Figure 1, it is conceptualized that consumers' decision to buy eggs produced from black soldier fly-based feed is directly influenced by their perception, consumers' socioeconomic, institutional and egg attributes. The willingness to pay then affects the uptake of eggs derived from black soldier fly-based feed. Egg attributes include yolk colour, size, relative price and type of feed used. Socioeconomic characteristics include age, gender, education, income. Institutional factors include time taken to walk to the nearest market, social network, source of nutritional information. Consumer perception was measured on a Likert five-point continuum scale of strongly disagree, disagree, undecided, agree and strongly agree. Consumers' perception and willingness to pay for eggs derived from black soldier fly larvae-based feed results in the uptake of these eggs.

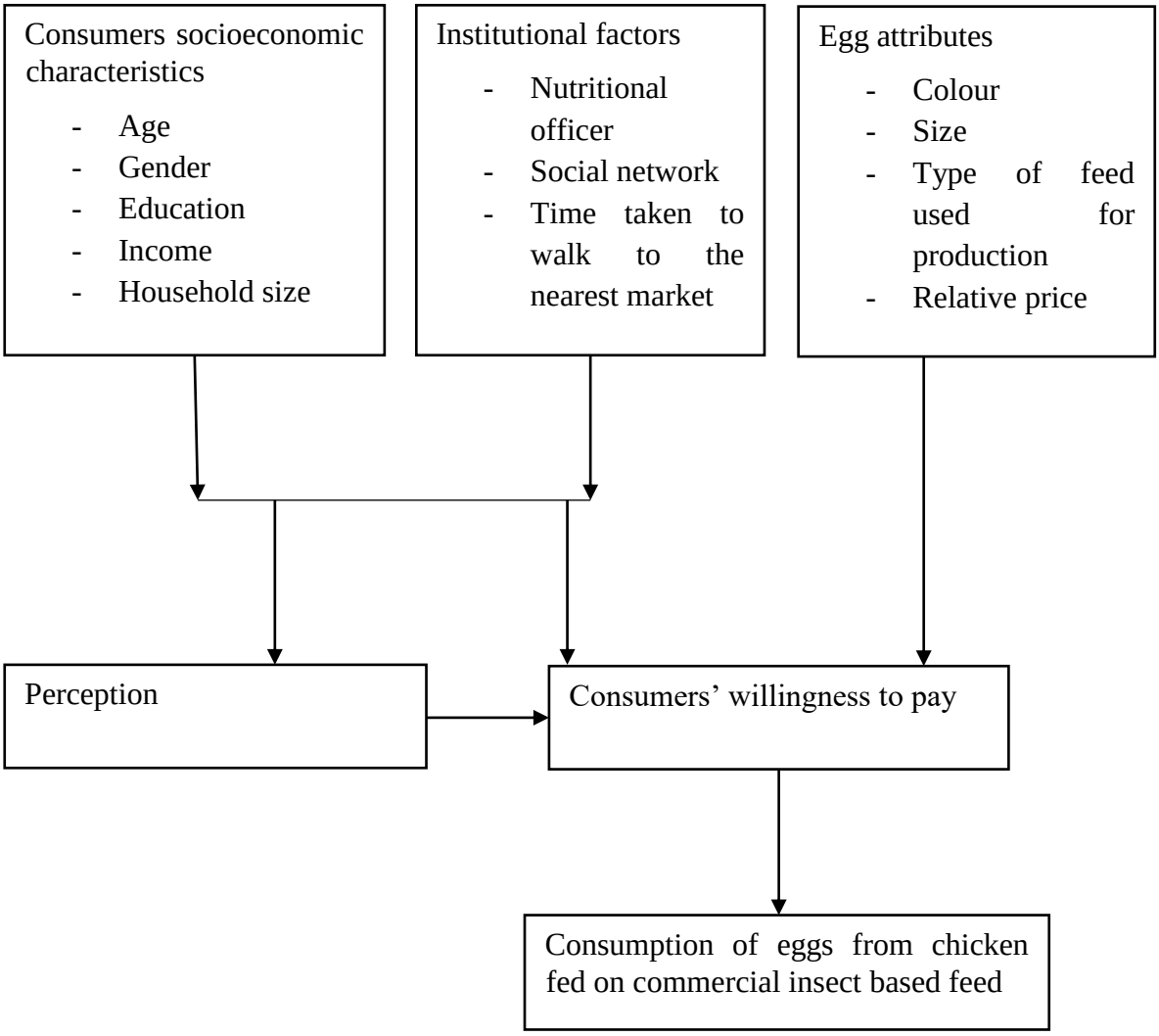

Figure 1: Conceptual framework

CHAPTER THREE
METHODOLOGY

The chapter gives information on the study area, sampling procedure and sample size determination. The last sections give information on data collection methods and sources, and analytical framework and priori assumptions of the study.

3.1 Research Design

This study used a descriptive research design. The design is used to describe characteristics of the target population. This research design was appropriate since the study aimed to explore the introduction of eggs produced from insect-based feed.

3.2 Study Area

The study was conducted in Kiambu county, Kenya. The study area was purposively selected for its high population density and predominant agricultural activities, especially poultry farming. Some of the most widely practiced agricultural activities include livestock production which entails dairy, poultry, sheep, goats, pigs, donkeys and crop production which entails cash crops such as tea and coffee and food crops such as maize, beans, pineapples and Irish potatoes. The 2009 census showed Kiambu had the highest chicken population which was estimated at 2,600,837. About 85% of chicken found in Kiambu are exotic breeds (KNBS, 2018).

Kiambu county is a vibrant commercial urban area that neighbours Nairobi and Kajiado Counties to the South, Nakuru to the West, Machakos to the East and Murang'a and Nyandarua to the North. The county lies between latitudes 00 25'and 10 20'South of the Equator and Longitude 360 31'and 370 15'East. It covers an area of 2538.6 square kilometers. The county enjoys a warm climate of 12-18 degrees and adequate rainfall of about1000mm each year. The cool climate makes the area an ideal choice to practice farming. The population was found to be 2,417,735 persons (Males 1,187,146 and females 1,230,454) thus a density of 952 persons per Km^2 (KNBS, 2019).

The county has one of the largest open-air egg markets in the Central region. Eggs are produced, sold and consumed throughout the year. Most eggs are taken to the market with some being supplied to other urban centers (County intergrated development plan Kiambu, 2018). Egg production is a high return investment agribusiness opportunity that can be exploited in Kiambu county. The feed challenge constraint in the value chain could be

remedied by introduction of cheaper options and help the economic growth of the poultry value chain.

The map of the study area is presented in figure 2.

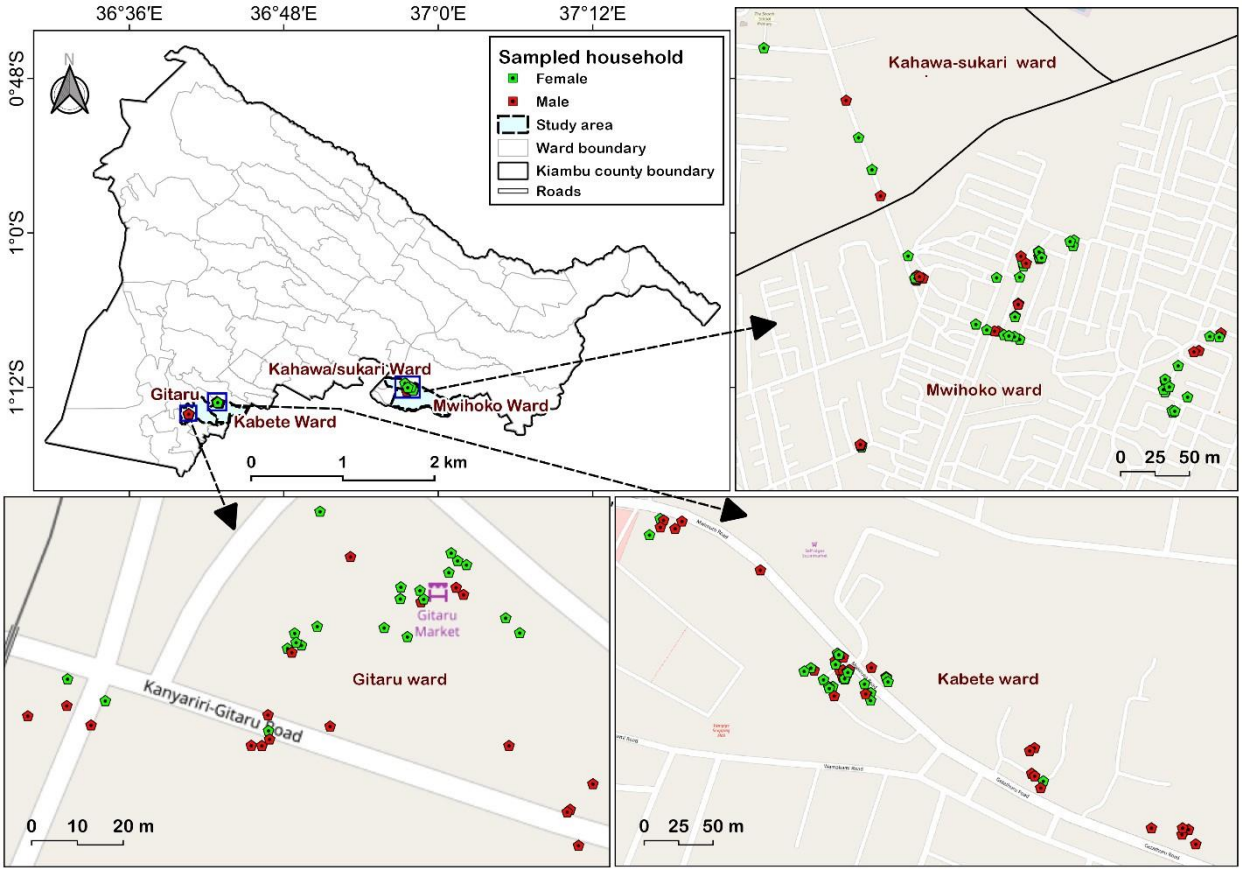

Figure 2: Map of Kiambu County

3.2 Sampling Procedure and Sample Size Determination.

The target population of this study was the residents of Kiambu County. The county was purposively selected due to it being a flagship area for insect for feed project. The consumers were randomly selected from jua kali areas and markets. Three sub counties (Kikuyu, Kabete and Ruiru) were randomly selected and consumers randomly selected from them. Hence, to establish the required sample size, Cochran 1977 sample size method was adapted (equation 5). Cochran method was ideal for this study because of the large population and this formula gives an ideal sample size.

$$n = \frac{pqZ^2}{e^2} \quad (5)$$

Where, n= the desired sample size; P=proportion of target population; q = (1-p), Z =critical value at 95% confidence level, e = Acceptable margin of error for proportion being tested. Since the proportion of the population was unknown, p =0.5, q =1-0.5 = 0.5, Z =1.96 and the desired level of precision e =0.07 based on the assumption that more than half of the population consumes eggs. The error term was chosen to account for both quantitative and qualitative errors. The sample size was therefore:

$$\frac{0.5(1-0.5)1.96^2}{0.07^2} = 196 \text{ Consumers} \quad (6)$$

Equation (6) shows that the desired sample size for this study was 196. However, a sample size of 200 households was used for analysis as 4 questionnaires were added during the data collection and included in the analysis.

Table 1. Sample Proportions Per Sub County

Sub County	Population size	Sample population selected
Kikuyu	187,122	$\frac{200}{757886} \times 187122 = 49$
Kabete	199,653	$\frac{200}{757886} \times 199653 = 53$
Ruiru	371,111	$\frac{200}{757886} \times 371111 = 98$
Total	757,886	200

3.3 Data Collection Methods and Sources

Primary data was collected from the respondents by use of a semi structured questionnaire. The questionnaire contained information on consumers' characteristics, institutional and egg characteristics and was administered through face-to-face interviews. The data was analyzed by use of STATA.

3.4 Analytical Framework

The data regarding objectives was analyzed as follows:

Objective one: To determine consumers' perception of eggs produced from chicken fed on black soldier fly-based feed a Likert type five continuum scale was used. The respondents were asked to rate their extent of agreement on perception which was on the scale of strongly agree, agree, undecided, disagree and strongly disagree. This was then analyzed by use of descriptive statistics to summarize the characteristics and Exploratory Factor Analysis (EFA) to obtain common factors that describe consumer preferences. EFA in equation 7 converted the large data set into constructs that are a logical set of uncorrelated factors. The principle underlying EFA is that p observed random variables $X = [\ x1, x2 \ldots xp]$ can be expressed as linear functions of $m < p$ latent factors, $F = [f1, f2 \ldots fm]$:

$$\text{Xj} = \sum \text{mk} = 1\ \lambda\text{jkfk} + \text{ej} \quad (7)$$

Where λjk, $j = 1, 2, \ldots m$ denote factor loadings and ej, $j = 1, 2, \ldots p$ are error terms or specific factors. The factors obtained from this analysis have the property that each factor is uncorrelated with all others and thus can used as dependent variables in the binary regression model in the second objective.

Objective two: To analyze socioeconomic and institutional factors that affect perception of eggs derived from black soldier fly larvae-based feed, was analyzed using a binary logistic regression. The factors created in objective one was used to create a normalized index of between 0-1 which was analyzed by binary logistic regression model. Normalization was done to change the values of the factors to a common scale of between 0-1 without distorting the difference in the ranges of the values. This was done to normalize the data by assigning standard scores in place of the predicted scores. The index was calculated as:

$$\frac{x-min}{max-min} \quad (8)$$

X being the index scaled between 0-1

Min being the minimum value in the scaled index.

Max being the maximum value in the scaled index.

A binary score was subsequently derived from the normalized scores; where scores equal to or greater than the mean were assigned "positive perception" and those less than the mean

assigned the "negative perception". The binary logit regression models consumers' perception of eggs produced from commercial poultry feed as a dichotomous choice. We assume that the dependent variable (Y_i) is binary i.e., 1= "positive perception" and 0= "negative perception" and a binary logit model is used to predict the socioeconomic and institutional factors that affect the outcomes as follows:

$$Y_i = \log\frac{(P_i)}{(1-P_i)} - \log Pi + \beta_0 + \beta_i X_i \quad (9)$$

Supposing: Pi= Positive perception (equation 10) and 1-Pi = Negative perception (equation 11):

$$P_i = \frac{1}{1+ e^{-Zi}} \quad (10)$$

$$P_i = \frac{1}{1+ e^{-Zi}} \quad (11)$$

Accordingly:

$$\frac{P_i}{1-P_i} = e^{\beta_i X_i + U_i} \quad (12)$$

$$\ln\frac{P_i}{1-P_i} = \beta_i X_i + \varepsilon_i = 1, 2, 3, \ldots, n \quad (13)$$

Where, xi is the set of independent variables, β_i is the coefficient of independent variables and ε_i is an error term as shown in equation 14. Therefore, the final equation was:

$$\ln\frac{P_i}{1-P_i} = \beta_0 + \beta_1 Age_i + \beta_2 Gender_i + \beta_3 Householdsize_i + \beta_4 Income_i + \beta_5 Timemarket +$$

$$\beta_6 offfarmincome_i + \beta_7 nutritiongroup_i + \beta_8 Information_i + \beta_9 credit_i +$$

$$\beta_{10} awareness_i + \beta_{11} kiosk_i + \beta_{12} farm_i + \beta_{13} market_i + \beta_{14} supermarket_i \ \varepsilon_i \quad (14)$$

Objective three: To determine consumer willingness to pay to pay for eggs produced with black soldier fly-based feed was analyzed in two parts. First, evaluation of consumers' preference for egg attributes by descriptive statistics: frequencies, tabular summaries and percentages.

Second, potential consumers' willingness to pay for eggs produced from chicken fed on commercial black soldier fly-based feed was analyzed using conjoint analysis and in particular choice based conjoint analysis (CBCA). This mainly focused on the change in attributes of the eggs. It is a multivariate technique, which utilizes the existence and combination of several variables, in this case attributes and levels. The consumer behavior that leads to a particular choice is modeled in a logical sequence, starting with tradeoffs among many attributes of a product or service and then followed by the decision on which attributes yield the maximum utility. Based on the nature of decisions, it is justified to use CBCA model whose estimation involves choosing specific attributes of the product or service followed by individuals making decisions between bundles of products profiles.

The first step involved choosing egg characteristics and the levels that were relevant to the consumer. After extensive review of literature, the following four potential attributes were selected: size, yolk colour, feed type used and price. Table 2 shows the summary of attributes and the levels to be used in CBCA.

Table 2. Attributes and levels of egg attributes used in CBCA.

Attribute	**Attribute level**
Size	Small
	Medium
	Large
Yolk Colour	Golden yellow
	Pale yellow
Feed type used	Conventional feed
	Black soldier fly larvae-based feed
Price	Sh. 10
	Sh. 12
	Sh. 14

The next step involved construction of hypothetical egg profiles with different attribute levels. The combinations contained one level of each attribute. Basically, this gave rise to a full factorial design of 36 (3x2x2x3) possible egg profiles. However, it was unrealistic to ask

individuals to choose among the combinations which give too many scenarios. Hence, a fractional factorial design using jmp software was used to reduce the egg profiles to a manageable size. This created orthogonal designs that were defined by their attribute level balance across the experiment, that is, levels of attributes across the choice design that are uncorrelated. The minimum number of choice cards was obtained by adding 1 to the total number of attribute levels and subtracting the total number of attributes from the result. In this survey there were 4 attributes and 11 attribute levels. The minimum number of choice cards was derived by adding 1 to 11 and subtracting 4; the outcome was 8. The total number of egg profiles was 8 as shown in the appendix section. Respondents then chose one option from the sample profile in Table 3, based on their preferences.

Table 3. A sample card of choice profiles

Egg characteristics	Egg 1	Egg 2	None
Size	Large	Medium	
Yolk colour	Pale yellow	Golden yellow	
Feed type	Black soldier fly larvae	Conventional	
Price per egg	10	14	
	☐	☐	☐
	I would buy option A	I would buy option B	I would neither buy option A or B

The CBCA approach is consistent with Lancastrian theory of value (Lancaster, 1966) which states that consumers do not derive utility from a good or service but from the various characteristics of the good or service. However, the empirical analysis of CBCA data is based on random utility theory (McFadden, 1974). Two alternatives have been widely used in analyzing CBCA: Conditional Logit (CL) and Random Parameters Logit (RPL) also known as mixed logit. CL has been used in most studies to analyze CBCA and assumes that consumers are homogenous in terms of taste and preferences (Mcfadden, 1974). However, similar studies in analyzing CBCA have found consumer preference for food products are heterogenous such that each consumer has a unique set of preferences (Tonsor *et al.*, 2009).

The CL model above is limited primarily in two ways. First, the model outlined assumes all respondents share the same coefficients for all relevant attributes, meaning they are assumed to have the same preferences for egg attributes. This is rarely the case, as preferences are not observable to the researcher, and they vary among respondents even in cases where their socio-demographic characteristics are identical. In many cases there is heterogeneity in preferences. Second, because consumer characteristics are fixed across all choices for each respondent, they are perfectly collinear with the intercept and must be dropped. This result prevents analysis of the effects of these characteristics on choice.

Following these limitations, random parameter logit (RPL) was used for this study as it provides the researcher with valuable information regarding the interpretation of the unobserved part of utility and provides unbiased estimates even if unobserved heterogeneity is present in the data (McFadden & Train, 2000). The RPL also provides wider options for policy interpretation as it allows for interaction of socio-demographic characteristics with the attributes of the good/service being studied. The (RPL)model is often used to investigate heterogeneity of preferences (Greene *et al.*, 2006). This method of analysis follows random utility model and is defined in equation 15 as:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad (15)$$

Where Uij is the i^{th} consumers' subjective utility of the choice of egg j under the hypothesis that this egg bundle affected preference, V_{ij} is the deterministic portion of the utility of choice preference and ε_{ij} is the stochastic component. The probability of choosing a choice set is:

$$P_r\{V_{ij} + \varepsilon_{ij} > V_{ik} + \varepsilon_{ik} \ for\ all\ k \epsilon C_i\} \quad (16)$$

Equation 16 shows C_i is the choice set for consumer I (C_i= {A, B, C), choice c= "None" in Table 3 and

$$V_{ij} = \beta_1 Price_{ij} + \beta_2 Feedtype_{ij} + \beta_3 Size_{ij} + \beta_4 Yolkcolour_{ij} + \varepsilon_{ij} \quad (17)$$

Equation 17 is the indirect utility of consumption function of option j for consumer I to be estimated.

In the RPL model the βs from equation 17 are allowed to vary across the population. In general, the consumer i had a coefficient vector given by

$$\beta_i = \beta + \sigma_{ui} \quad (18)$$

Where, β is the population mean, Ϭ is a diagonal matrix of coefficient of standard deviations and u is a vector of independent standard normal deviates. The specification on equation 18 assumes the coefficients vary randomly over individuals to capture the potential variation in tastes for specific egg attributes and relaxes the restriction that every respondent exhibits constant marginal utilities for egg choice attributes.

RPL is not subject to the independence from irrelevant alternatives assumption found in the CL model and accounts for the repeated observations taken from each respondent (Greene *et al*., 2006). The results of the model provide an indication of variability of egg attribute preferences within the sample. The price coefficient is assumed fixed in the population. Point estimates of WTP are obtained in the above approach by

$$WTP = \frac{\beta_0}{\beta_{price}} \quad (19)$$

Where β_0 being coefficients value of non-price attributes for egg and β_{price} being coefficients value of price for egg holding all other potential influences constant. The ratio of the attributes to the price represents the WTP (implicit price or part-worth). This represents trade-offs between egg attributes and cost (price of one egg) attribute, which is the marginal WTP. Therefore, WTP indicates the marginal rate of substitution (MRS) between the other attributes and the cost attribute.

Table 4. Definition of Variables Used in the Binary and Random Parameter Logistic models

Variables	Definition	Measurement	Hypothesized sign
Perceived benefits	Consumers view benefits of eggs produced from chicken fed on commercial black soldier fly larvae-based feed	1=positive perception, 0=negative perception	
Ethics	Consumers view ethical issues regarding eggs produced from chicken fed on commercial black soldier fly larvae-based feed	1=positive perception, 0=negative perception	
Traceability feed	Consumers view on traceability of feeds used for egg production	1=positive perception, 0=negative perception	
WTP	Willingness to pay for eggs produced from chicken fed on commercial black soldier fly larvae-based feed	Continuous	

Independent Variables			
Age	Age of purchaser in years	Age of consumer(continuous)	+
Gender	Gender of purchaser	Gender (dummy 1=male, 0=female)	+/-
Household size	Total number of household members	Continuous	+/-
Income	Monthly income of the household	Categorical	+/-
Time to market	Time taken to walk to the market	Continuous	+/-
Egg attributes	Important egg attributes to consumer	Categorical	+
Access to credit	Access to credit for purchasing food in the past 12 months	Categorical	+/-
Awareness	Aware of the use of insects as chicken feed	Categorical	+/-
Group membership	Membership to nutrition groups	Categorical	+/-
Nutrition information	Access nutritional information	Categorical	+/-
Kiosk	Having kiosk as the most preferred retail outlet.	Categorical	+/-
Open air market	Having open air market as the most preferred retail outlet.	Categorical	+
Supermarket	Having supermarkets as the most preferred retail outlet.	Categorical	+/-
Farm gate	Having farm gate as the most preferred retail outlet.	Categorical	+

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

This chapter is divided into four major sections. The first section discusses the descriptive results comprising consumers' socioeconomic characteristics. In the second section, exploratory factor analysis results are discussed. Empirical results of Binary regression model and mixed logit regression models are discussed in sections three and four respectively.

4.2 Descriptive results

This section presents descriptive statistics of variables used in the regression models. Table 5 presents results of the consumers' age, time taken walking to the nearest market, household size and egg consumption per week. The mean age was 36.5 years (range = 18-73), this implies that many young people live in Kiambu County. This result is in line with statistics that show most peri-urban areas are populated by young people (KNBS, 2017). Most households had an average size of four members. Joel (2018) study which assessed acceptance of chicken meat derived from insect-based feed in Kenya differ on household size in Kiambu county with the current study by one member. The average time taken walking to the nearest market was 11.5 minutes. Time taken walking to the nearest market determines consumer ease of access to food. Longer distance to market constrains access to food commodities due to high transportation costs. Previous studies have shown consumers are less willing to shop from markets that are distant from their homes (Gido *et al.*, 2016).

Table 5. Description of continuous variables for consumers (%)

Variable	Mean value	Std. Error	t - value
Age	36.52	10.90	1.77
Time taken walking to market (minutes)	11.5	12.00	1.35
Household size	3.76	1.77	-0.51
Number of times eggs are consumed per week	2.81	1.55	-2.49**

Note: ** = significant at 5% level

Table 6 presents results for categorical data. Among the consumers, 52.00 percent were female. Probably, in most households the females are concerned with purchase of food for the

family. The gender of the person who purchases food influences the food choice thus, male purchasers tend to choose foods that seem innovative while female purchasers are more concerned with health and nutrition aspects (Kajale & Becker, 2015). Most consumers participated in off-farm income generating activities at 70.50 percent. This could be attributed to higher exposure to business opportunities since Kiambu County is a peri-urban area. Off-farm income comprised of income from business, employment, and any other income apart from farm income (Kassie *et al*., 2013). Off-farm income has shown to improve disposable income hence increases food purchasing options. It also improves exposure to variety of food choices, and this could enhance the food purchaser's decision making (Alemu *et al.,* 2015).

Table 6. Descriptive Statistics for categorical variables for consumers (%)

Variable	Description	All households (n=200)	χ^2 Value
Gender	Female	52.00	61.75***
	Male	48	
Off-farm income	Yes	70.50	5.03**
	No	30.50	
On-farm income (% yes)			17.60***
<10,000	Yes	33.00	
10,001-20,000	Yes	34.00	
20,001-30,000	Yes	17.00	
30,001-40,000	Yes	9.00	
>40,001	Yes	7.00	
Access to credit (% yes)	Yes	54	0.33
	No	46	

Note: **, *** = significant at 5% and 1% level respectively.

In terms of income, more than half of the consumers (67 percent) had relatively low income of below Ksh. 20,000. Consumers' income is important when studying ex-ante demand of food products since amount of money allocated for food purchase is allocated from it.

Table 7 presents results for information sources. Nutrition information was significant at 1 percent level with only 27.50 percent of households getting nutritional information. In terms of group membership to food security groups, membership was low at nine percent. Previous studies have shown information dissemination as a key driver towards the acceptance of new technologies. Group membership creates platforms for information sharing, reduces information sharing costs and motivates acceptance of new technologies (Zamasiya *et al.*, 2017).

Table 7. Descriptive statistics for sources of information for consumers (%)

Variable	Description	Consumers (n=200)	χ^2 Value
Nutrition information	Yes	27.50	7.29***
	No	72.50	
Group membership	Yes	9.00	4.00**
	No	91.00	

Note: **, *** = significant level at 5% and 1% respectively

The percentages of retail outlets used are presented in Table 8. The open market was the most frequented purchase outlet. Open air markets are known to be convenient, offer variety and fresh and nutritious agricultural produce (Cherono & Otieno, 2016). Kiosk was the second most popular purchase outlet at 44 percent. Kiosks could be many and near residential areas, so consumers found it easy to purchase from them. According to Alemu *et al.* (2017) urban consumers have shown to prefer kiosks for food purchases because they are reliable and convenient. Supermarkets were the least referred purchase outlets. Consumers associated supermarkets as being expensive and not having fresh food products.

Table 8. Frequently Used Purchase Outlets by Consumers (%)

Variable	Description	Consumers	χ^2 Value
Open market	Yes	55.50	1.67
	No	44.50	
Kiosk	Yes	44.00	0.37
	No	56.00	
Farm gate	Yes	41.50	0.02
	No	58.50	
Supermarket	Yes	2.00	0.04
	No	98.00	

About 65.5% of the consumers were aware that insects can be used as protein source in chicken feed. The fact that more than half of the consumers were aware that insects are a source of chicken feed shows that some consumers are well versed with this concept. This finding tallies with Chia *et al*. (2020) and Joel (2018) who reported most of the respondents interviewed in Kenya were aware that chicken feed on insects. However, Chia *et al.* (2020) findings indicated more awareness among farmers. This might be due to the fact that this consumer study was conducted in a peri-urban region and hence an assumption that consumers may be less familiar with poultry farming. In addition, consumers were more aware of some insects unlike others as indicated in Figure 3. Termites, crickets, and grasshoppers were the most commonly known among the consumers. This result is in line with Alemu *et al.* (2015) study which shows consumers in Kenya eat termites as a protein source. Hence, consumer awareness of these insects might be attributed to their experience with them as a food source. Despite consumers being aware of the use of insects in poultry feed, there is low awareness on use of black soldier fly larvae (10%). Similarly trends on low awareness on black soldier fly larvae as a source of protein in feed were obtained in Kenya.

Joel (2018) documented that most consumers were not aware on the use of black soldier fly larvae as feed due to them not being bothered to know what chicken feed on. This indicates that there is need to sensitize the consumers on black soldier fly larvae as it is the most

promising source of protein. It also has additional benefits of being cost effective, all year production and use in waste management (Diener *et al*., 2009; Dortmans *et al*., 2017).

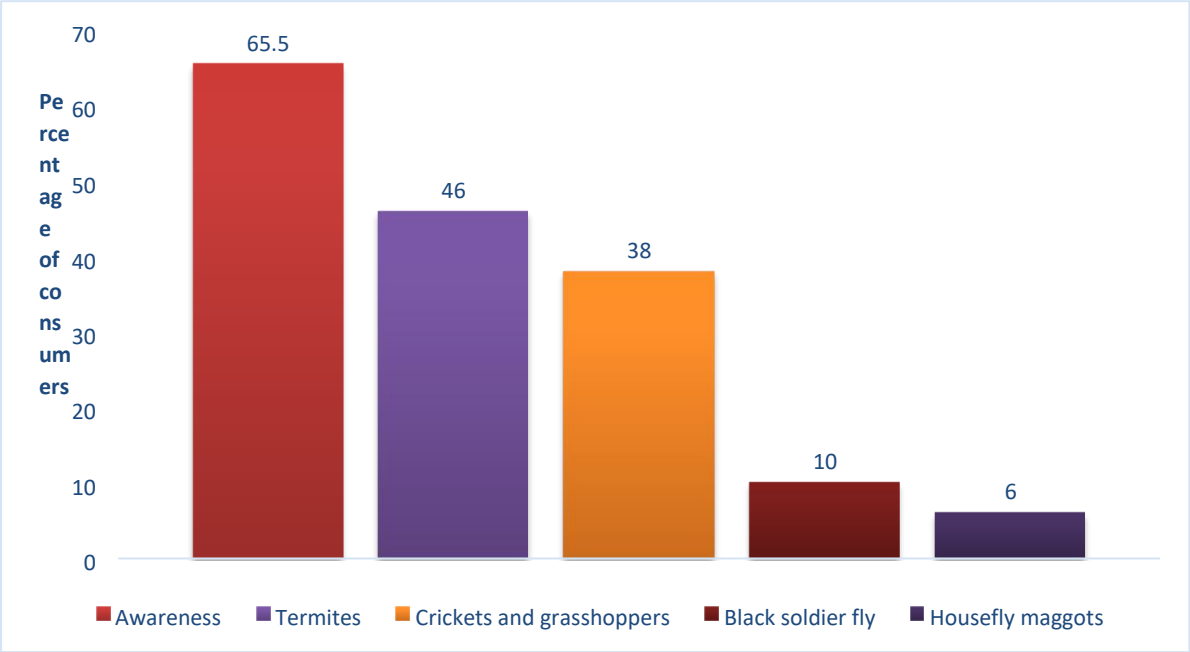

Figure 3. Percentage Awareness of Insect as Chicken Feed

Overall, only 6% of the consumers were aware of the use of housefly maggots as a source of chicken feed as shown in figure 3. Most consumers, 46 percent, were aware of the use of termites and related them to free range chicken that feed on them. This is in line with findings that most free-range chicken feed on insects in backyard rearing systems (Nyaga, 2007). Respectively 38 and 10 percent of consumers were aware on the use of crickets, grasshopper's and black soldier fly larvae as chicken feed. Consumers have shown to accept edible insects and insect products if they have information on the products (Alemu *et al.*, 2015; Verbeke *et al.*, 2015). However, in the current study, though some insect-based products might be in the market, there is no awareness of commercial availability of insect-based poultry feed. Hence, there is a likelihood that consumers will trust these products if they are introduced in the market.

The two types of eggs in the market are conventional (grade) eggs which are produced from commercial layers and local (*kienyeji*) eggs which are produced from locally bred chicken. Figure 4 shows the preference for the type of eggs. About 51 percent of consumers preferred local eggs as shown in Figure 4.

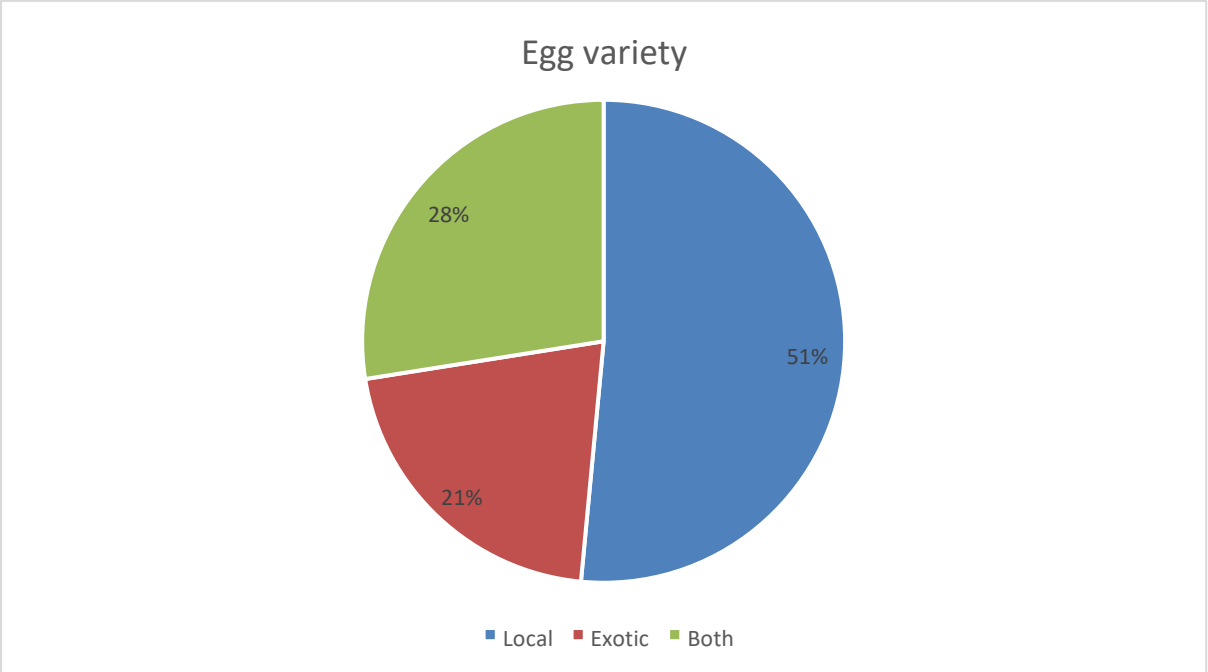

Figure 4. Percentage of Consumers' Preference for Egg Variety

A crosstabulation of reason for preferred eggs shows preference for local eggs is for their nutritional value and are viewed as healthy alternatives. Conventional eggs are preferred due to their affordability and availability. 73 percent of consumers associated local eggs with their nutrition value. Only 21 percent of consumers preferred conventional eggs. They were mainly associated with affordability.

Table 9. Crosstabulation for Reason for Purchase of Egg Variety

Variety of eggs	Reason for purchase (% of consumers, n=200)			
	Availability	Affordability	Nutritious	Healthy
Local	16.00	5.00	73.39	77.27
Conventional	41.33	53.33	1.83	1.82
Both	42.77	41.67	24.77	20.91
Total	100	100	100	100

The source of awareness of the different types of insects as feed is indicated in Figure 5. Very few consumers had their source of awareness of insect as feed from *icipe*. 50 percent of consumers had their information from media sources such as newspapers, internet and social media apps such as Facebook. This can be attributed to growing use of internet services to access information. This was followed by receiving information from extension officers at 25

percent. During the interviews, consumers admitted to not being concerned with what chicken feed on and this might affect their awareness levels for the different types of insects available for use in chicken feed. This can be assumed to be because consumers have non-farm occupations hence have less interest in knowing what chicken feed on.

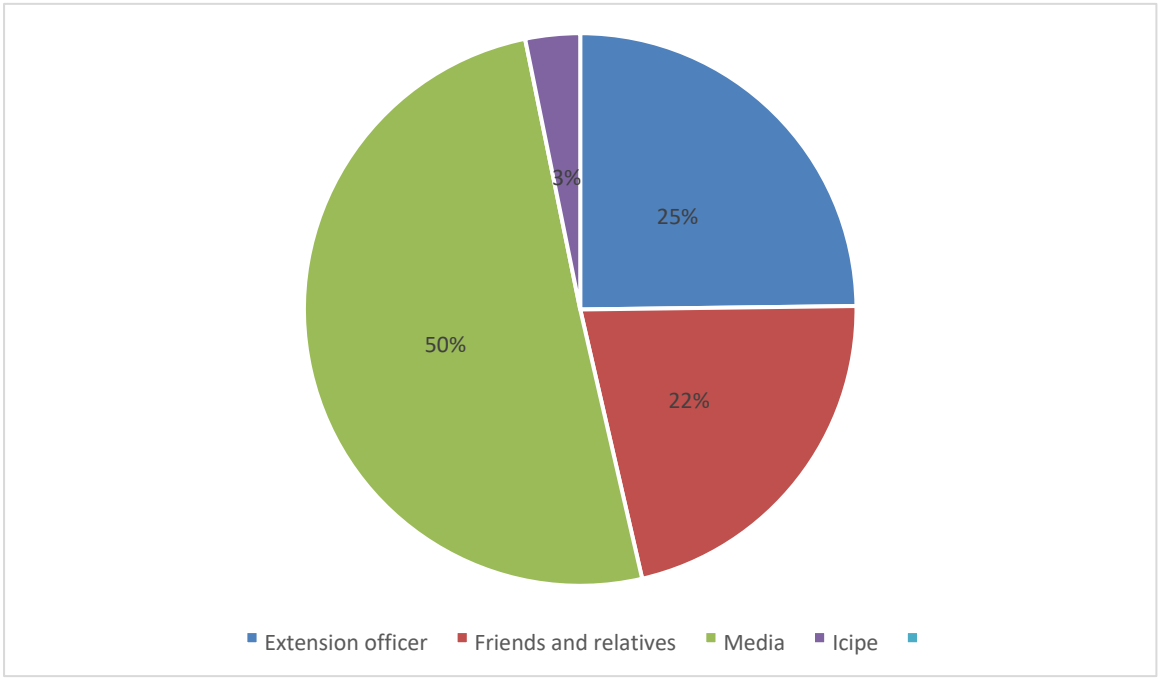

Figure 5. Source of Awareness on the Use of Insects in Poultry Feed

4.2. Consumer perception of eggs produced from insect-based feed.

To determine consumers' perception of eggs produced from commercial insect-based feed in Kiambu county was analyzed using exploratory factor analysis (EFA). EFA identifies the underlying constructs that make up the complex data retaining all the important information from the original data (Yong & Pearce, 2013). A Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy of 0.733 (minimum required threshold is 0.50) showed that EFA was appropriate.

Furthermore, Bartletts' test of sphericity yielded a p-value<0.05 indicating a patterned relationship among the variables. A total explained variance of 95% out of the proportion of the original data explained, a satisfactory amount in social sciences (Hair *et al.*, 2010). Therefore, the three factors with Eigen values greater than one were vital in explaining variability in the dataset.

Following some adaptations of Verbeke *et al*. (2015) and Joel (2018) work, the components were labelled according to similarities of the statements that had significant loadings on them.

The factors were labeled ‘perceived benefits’, ‘ethics on the use of black soldier fly’, and ‘traceability of feed’. Table 10 presents the factor loadings of perception variables on the extracted factors after orthogonal varimax rotation. The factor loadings above the threshold of 0.5 were retained for each factor. The total variance accounted for was 95% with factor 1 accounting for 47.17 %, factor 2 for 30.11% and factor 3 for 18.41%. Cronbach’s alpha coefficient was computed to examine the internal consistency and was 0.804 which is a good measure above the threshold of 0.70.

Table 10. Table 10. Rotated Factor Matrix of Consumers' Perception

Perception statements	Factor 1	Factor 2	Factor 3
I have adequate knowledge on feeds fed to chicken for egg production	0.2244	-0.0046	0.2554
I take into consideration what layer chicken are fed on before I buy eggs	0.0777	0.0851	0.5498
I am not bothered about what the chicken were fed on before I buy eggs	-0.0422	-0.0279	-0.5423
Eggs produced from chicken fed on black soldier fly larvae meal are the same as eggs produced from chicken fed on conventional feed	0.1351	-0.0824	-0.1276
Eggs produced from chicken fed on black soldier fly larvae meal are same as fish and meat	-0.1585	-0.0446	-0.2901
I would buy eggs produced from chicken fed on black soldier fly larvae meal regardless of the price	0.359	0.0801	0.4062
Eggs produced from chicken fed on black soldier fly larvae meal are hygienic	0.7724	-0.0751	0.21
Consuming eggs produced from black soldier fly larvae meal is healthy	0.7438	-0.1912	0.0627
I would buy eggs produced from chicken fed on black soldier fly larvae meal only if recommended by health authorities	0.1116	0.1917	0.2265
Eggs produced from chicken fed on black soldier fly larvae meal have chemical residue	0.5331	-0.0346	-0.0368

Consuming eggs produced from chicken fed on black soldier fly larvae meal is environmentally friendly	0.6912	-0.2751	0.035
Eggs produced from chicken fed on black soldier fly larvae meal are rich in nutrients	0.8233	-0.1729	-0.0697
Eggs produced from chicken fed on black soldier fly larvae meal are medicinal	-0.1027	0.3009	-0.0756
Eggs produced from chicken fed on black soldier fly larvae meal are a luxury	-0.2162	0.0075	-0.1477
Use of insects as chicken feed will lower the price of eggs	-0.1853	0.8636	0.0839
Use of black soldier fly larvae as chicken feed goes against my religious beliefs	-0.1753	0.867	-0.0245
Use of black soldier fly larvae as chicken feed goes against my culture	0.0035	0.2983	0.2905
Eggs produced from black soldier fly should be labeled	18.00	12.50	20.50
Total variance explained (%)	47	30	18
Cumulative variance explained	47	77	95
Suggested interpretation	Perceived benefits	Ethics	Traceability

Note: (1) Factor loading taken is >0.4 are in bold and eigenvalue is over 1. (2) Kaiser-Meyer-Olkin (KMO) of sampling adequacy= 0.733

Factor 1, Perceived benefits, loaded on statements related to the benefits associated with eggs produced from insect fed hens. This factor captured consumers' tendency to accept consuming eggs based on related and contextual attributes. In addition to these variables, other variables reflecting perks of these eggs such as being environmentally friendly and having no chemical residue loaded positively on this factor.

The second factor, ethics loaded on statements related to moral principles that govern consumers' behaviour. This factor is loaded on statements that reflect consumers' cultural and religious beliefs about eggs from insect fed chicken. The third factor, traceability, is loaded on statements related to potential to find the origin of these eggs such as knowledge on poultry feed. The derived factors from EFA (perceived benefits, ethics and traceability), were treated as dependent variables in the binary regression logit model to determine the factors that influence consumers' perception of eggs produced from insect-based feeds.

4.3. Factors Influencing Consumers' Perception of Eggs Produced from Commercial Insect-based Feeds.

4.3.1. Preliminary Diagnostics of the Variables Used in the Regression Models.

Diagnostic tests were done to determine how well the model fit the data. Multicollinearity and heteroscedasticity problems are very common in cross-section data. As a result, tests were run on the data to determine whether these issues existed.

(a) Testing for Multicollinearity

High correlations between the independent variables in a regression model are a sign of multicollinearity (Gujarati, 2009). This causes major issues with sign change as well as accurate assessment of the structural relationships among the variables that the regression methods seek to identify. Wide confidence intervals between the confidence intervals of the coefficients and small statistics are caused by the presence of multicollinearity among the variables. Assessing the relative significance of the independent factors explaining the variance brought on by the dependent variable becomes difficult as a result (Gujarati, 2009). As a result, when multicollinearity is present in a study, it is challenging to reject the null hypothesis. The pairwise correlation presented in appendix 2 confirmed there was no serious correlation among the variables in the current study. Similarly, VIF results showed there was no strong relationship among the continuous variables since the values were less than 5. Therefore, all proposed potential independent variables were used in the regression analysis.

(b) Testing for heteroscedasticity

When a variable's variance fluctuates all throughout a wide range of values in observations, this phenomenon is referred to as heteroscedasticity. This phenomenon may occur in regression models because the data set has a large range between the largest and smallest observations. If found present, it causes the coefficient to be less precise hence it increases the likelihood that the coefficient is further from the correct population value. It also increases the variance of the coefficient estimates hence the variance of the error term is not constant. There are various methods that may be used to solve this issue, this may include redefining variables or for linear models the supplemental regression-based White's general heteroscedasticity test can be employed. (Gujarati, 2009). The current study was a logit model hence the Breusch-Pagan test was applied and showed there was no bias and inconsistence in parameters variances. The chi² was 4.80 which was small, and the p value was 0.98; hence the heteroscedasticity problem was minimal in the model.

To determine the socioeconomic and institutional factors that significantly influence consumers' perception of eggs produced from chicken fed on commercial insect-based feed in Kiambu County, was analyzed by the binary logit regression. Each of the three factors estimated using EFA was estimated using the consumers' socioeconomic characteristics. The dependent variables were perceived benefits, ethics and traceability. The binary logit was suitable as the factors were converted to an index and converted to a binary response of "positively perceive" and "negatively perceive". The results of the binary logit on the independent variables are presented on three different perception aspects: Perceived benefits, ethics and traceability.

Table 11 presents the binary logit results of factors that influenced consumers' perception of eggs from insect fed chicken. For each respondent, we predict the retained component for the three factors and regress the predicted scores against the household characteristics outlined earlier. The results show that only eight independent variables have significant association with consumers' perception of eggs produced from black soldier fly larvae-based feeds. The variables that were found to have a significant association with consumers' perception on eggs produced from black soldier fly larvae-based feed included access to credit at 5% and 1%, off-farm income at 1%, awareness at 1%, on-farm income at 5%, household size at 1%, kiosk at 5% and open-air market as a purchase outlet at 5%. Male headed households are more concerned about the traceability aspect. This implies that male headed households are concerned with what chicken feed on unlike their female counterparts.

Household size positively predicted consumers' perception of the ethics factor. Larger households were more concerned with the ethics factor. Average income earners in comparison to low-income earners that is the base category are more concerned about the benefits of eggs but as income increases, the less the concern by consumers. This might be caused by the fact that as income increases, the consumers are able to have access to a variety of other protein sources. Kisaka *et al.* (2018) found similar results where an increase in income reduced the likelihood of accepting termites as a food source. Consumers who have access to credit are concerned about the benefits and ethics. It is possible that access to credit may increase disposable income and consumers may want to increase their dietary diversity by purchasing new food products such as eggs produced from black soldier fly larvae-based feed in the market. However, regarding ethics factor, access to credit had a negative effect on the perception. This is in line with findings from Domingues *et al.* (2020) that consumers perception on the use of insects in animal feed decreased when income increased. Consumers who had more access to credit were less likely to perceive the ethics factor.

Consumers who had other sources other than agriculture were more likely to positively perceive the perceived benefits factor. The coefficient on off-farm employment these are consumers who receive income from sources other than farm income was identified as having a positive effect on perception. This indicates that those who received off farm income were more likely to positively perceive eggs derived from black soldier fly larvae-based feeds. Off-farm income activities could have increased exposure to information on Food products from insect-based feed and have supplementary disposable income and can therefore access a variety of foods. According to Verbeke *et al.* (2015) farmers were more critical than other citizens of the use of insects in animal feed as they were skeptical on availability of insects. In contrast, our results show that those with farm employment were more willing to accept the use of insects in poultry feed.

The more one is aware the more the benefits of these eggs are important. This finding implies the more aware consumers are of the use of insects the more they are willing to positively perceive eggs derived from black soldier fly larvae-based feed. These results are in line with previous literature that found that individuals who were aware of new products had positive perception towards them (Angulo & Gil, 2007; Verbeke *et al.*, 2015). Sogari *et al.* (2017) also reported better consumer acceptance of edible insect-based food when introduced into the market after considerable press and mass media coverage on entomophagy. The coverage attracted consumer interest in the topic and increased knowledge due to better

information on the topic being available. Exposure and information on use of insects affects people's choices on food they choose to consume (Tan *et al*., 2015). This could suggest a possible pathway for positive perception that begins with awareness, which generates information that can lead to consumers' acceptance of eggs derived from black soldier fly larvae-based feed.

Those who buy from open markets are concerned about traceability and perceived benefits issues. Probably because the consumers who purchased in open air markets were exposed to a larger variety of eggs and might want to know where the eggs come from and advantages over the different egg types before purchase. Those who buy from kiosks are also concerned about traceability. Most consumers preferred to buy their eggs from open markets and kiosks. This could be due to their ease of access and reliability.

Table 11. The Estimated Coefficients of the Binary Logit for Consumer Perception on Egg Production Using Insect-based Feeds in Hen Diets

Explanatory variables	Binary Regression Parameter Estimates			
	Perceived benefits	Ethics	Traceability	VIF
Age	0.001 (0.017)	0.004 (0.016)	-0.024 (0.016)	1.23
Gender	0.378 (0.413)	-0.495 (0.380)	0.778(0.366) **	1.19
Household size	0.076 (0.100)	0.310 (0.103) ***	0.0105 (0.092)	1.14
Income (base Ksh <10,000)				
Ksh 10001-20000	0.909 (0.427) **	-0.123 (0.407)	0.279 (0.394)	1.5
Ksh 20001-30000	1.041 (0.525) **	-1.021 (0.510) **	-0.033 (0.466)	1.37
Ksh 30001-40000	0.485 (0.641)	-0.316 (0.614)	-0.348 (0.598)	1.24
Ksh >40001	1.009 (0.821)	-0.222 (0.675)	-0.969 (0.714)	1.29
Access to credit	0.999 (0.340) ***	-0.825 (0.323) **	-0.009 (0.311)	1.03
Off-farm income	1.270 (0.431) ***	-0.004 (0.392)	0.178 (0.372)	1.24
Distance to market	0.013 (0.016)	0.015(0.014)	-0.005 (0.014)	1.21
Nutrition information	0.232 (0.417)	0.744 (0.392)	0.534 (0.385)	1.21
Group membership	-0.889 (0.621)	0.130 (0.621)	0.091 (0.581)	1.18
Awareness	1.407 (0.374) ***	0.608 (0.342)	0.226 (0.332)	1.06
Open air market	0.936 (0.433) **	-0.976 (0.407)	0.851(0.398) **	1.57
Kiosk	0.374 (0.440)	-0.710 (0.406)	0.824(0.407) **	1.61
Supermarket	1.923 (1.396)	-2.289 (1.323)	2.086 (1.483)	1.19
Farm gate	0.403 (0.413)	-0.680 (0.388)	-0.203 (0.373)	1.46
Constant	-3.720 (0.963)	-0.046 (0.817)	-0.416 (0.804)	
Adjusted R-squared	0.2171	0.1503	0.0953	
Observations (n)	200			

Note: VIF = Variance inflation factor; *** = significant at 1% level and ** = significant at 5% level. Standard errors are in parentheses.

4.4 Willingness to pay for eggs produced from chicken fed on commercial insect-based feed

4.4.1 Consumers' expression of preference of egg attributes

Consumers were asked to indicate whether they considered the egg attributes important when purchasing eggs and results are presented in Table 12. Generally, about 86 percent of consumers were positively concerned about price. These findings imply that appropriate pricing of eggs is one of the most essential elements that will attract consumers. This is because consumers attach value for money to the utility received from the product (Lien *et al*., 2015). Feed type used and the size of the egg had a positive concern, this implies that consumers consider the size of the egg, or the feed type used in the production of the egg when purchasing. Sensory attributes such as size and price are important attributes that consumers perceive important as they are easily observable when purchasing eggs (Ayim-Akonnor & Akonnor, 2014; Rondoni *et al*., 2020). Most consumers perceived the selected egg attributes as important, this implies that these attributes are useful in understanding consumers' preferences and WTP for eggs derived from black soldier fly larvae-based feed.

Table 12. Respondent Perception on Importance of Egg Attributes

Attributes	Percentage of responses(n=200)
Price	86.0
Size	79.0
Feed type used	70.5
Yolk colour	57.5

4.4.2 Preferences for egg attributes

RPL model was used to account for potential heterogeneity. The results obtained are shown in Table 13. Price was used as a constant term and other attributes were allowed to vary randomly in the population. The price coefficient was negative as expected, this indicates that increased demand and follows the law of demand that increase in price is associated with marginal disutility. The positive signs and statistical significance on the other attributes indicate the importance of these attributes to consumers. Although size is a significant factor, there is a higher positive coefficient for small eggs than for large eggs, this indicates that small eggs elicit more demand than large eggs.

Table 13. Estimated Coefficients for The Random Parameter Logit Model

Attributes	Coefficient	Standard error	P value
Price	-0.167	0.046	0.000***
Small	1.450	0.203	0.000***
Large	0.918	0.197	0.000***
Golden yellow yolk	1.912	0.163	0.000***
Black soldier fly larvae-based feed	0.893	0.140	0.000***
Derived standard deviations of parameter distributions			
Small	0.062	0.171	0.719
Large	-0.302	0.229	0.188
Golden yellow yolk	0.715	0.146	0.000***
Black soldier fly larvae-based feed	1.131	0.122	0.000***
Log likelihood	-918.380		
Adjusted Pseudo-R^2	0.393		
n (respondents)	200		
Number of observations	4800		

*** Significant at 1%

Contrary to a *priori* expectation, consumers are significantly willing to pay more for small eggs in comparison to large eggs. The higher preference for smaller eggs might be because consumers view these eggs as not having any enhancements thus being presumed to be more natural (Ayim-Akonor & Akonor, 2014). Consumers seemingly prefer large eggs. Consumers believe large eggs have more content and can get value for money they spend on purchasing eggs. The positive significant preference for black soldier fly larvae-based feed is consistent

with recent studies on acceptance of insect-based food products which position insect-based foods as preferred to consumers in the growing population (House, 2016; Szendr, 2020; Verbeke *et al*., 2015). This implies that consuming food products derived from insects is highly acceptable in this society. As a result, eggs derived from black soldier fly larvae-based feed are likely to be preferred. With changing preferences in consumers, insect-based foods are generally viewed as an alternative to protein-rich foods that use conventional proteins. Therefore, insects are viewed as an alternative to replace conventional proteins as a protein source in animal feed (Van Huis *et al*., 2013).

The attribute golden yellow yolk eggs had a positive and significant preference. Further research shows that consumers associate golden yellow yolk eggs with health and nutrition benefits (Hasin *et al.*, 2006). The inclusion of black soldier fly larvae in chicken feed has shown an increase in yolk colour and as such would address the issue of having a golden yolk colour. Additionally, there has been an increase in the marketing of golden yolk eggs in the market as they are thought to be more nutritious tasteful and attractive than others. This finding is in line with Senbeta *et al.* (2015) who reported that majority of consumers in Ethiopia preferred golden yellow yolk eggs as it was perceived to be highly nutritious.

Willingness to Pay (WTP) estimates were calculated as the ratio of the partial derivative of the utility function with respect to the attribute of interest, divided by the derivative utility function with respect to price. Thus, WTP for each attribute is a ratio between the estimated attribute and price parameters, multiplied by -1. The WTP estimates presented in Table 14 demonstrate that the highest WTP is associated with golden yolk colour.

The attribute coefficients for golden yolk colour and black soldier fly larvae-based feed have highly significant derived standard deviations. This shows that consumers have heterogenous preferences for these egg attributes. This suggests that the preferences for these attributes are influenced by unobservable factors. This finding is in line with Arbive-Bortsi *et al.* (2022) who reported that consumers in Ghana preferred golden yellow yolk eggs and associated it with higher nutritional value. The price attribute coefficient estimate is significant and with the expected negative sign. This enables the computation of marginal WTP estimates which represent the monetary value that consumers attach to the various egg attributes. The WTP is the ratio of other attribute coefficients and the egg price coefficient estimate. Table 14 presents the marginal WTP estimates for egg attributes. These results reveal that consumers have heterogenous preferences for egg attributes. Consumers are willing to pay higher

amounts Kshs 6 to Kshs 17 per egg for golden yolk eggs compared to any other attribute. This shows golden yolk eggs are more valuable and therefore more preferred by consumers. Nevertheless, consumers are willing to pay Kshs 3 to Kshs 13 for small eggs; Kshs 1 to 10 for large eggs; Kshs 1 to Kshs 9 for eggs derived from black soldier fly larvae-based feed which is relatively low this might be associated with unfamiliarity with insect-based feed.

In Table 13 the standard deviations were used to explain the heterogeneity in factors that affect the choice preferences by consumers that are unaccounted for in the model. Attributes of golden yellow yolk eggs and use of black soldier fly larvae-based feed were significant, and this indicates that there might be other factors that affect how consumers choose these attributes when purchasing eggs.

Table 14. Marginal WTP Estimates for Egg Attributes

Attributes	MWTP	Lower limit	Upper limit
Small	8.70	3.56	13.84
Large	5.51	0.94	10.08
Golden yellow	11.47	5.55	17.40
Black soldier fly-based feed	5.36	1.37	9.35

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the conclusions of the study, policy recommendations and areas of further research.

5.2 Conclusions

i. Consumers perceive eggs produced from insect fed hens positively with perceived benefits and ethically appropriate.
ii. Positive perception of eggs produced from insect fed hens is determined by awareness of use of insects in chicken feed.
iii. Consumers are willing to pay for eggs produced from insect fed hens and the major significant determinant of WTP is price.

5.3 Policy Recommendations

i. Commercialization of insect feed for chicken to boost production of eggs as consumers have a positive perception of it.
ii. Create awareness and disseminate information on the nutritional value that insects such as black soldier fly add in poultry feed.
iii. There is a need for policy makers to create a favourable environment through formulation of policies that allow the use of insects in commercial chicken feed to benefit egg production in Kenya.

5.4 Areas of Further Research

i. This study used stated preferences to get the consumers perception and WTP of eggs produced from insect-based feed. Therefore, a further study can be done including sensory attributes to enable consumers to tell the actual difference of these eggs.
ii. Further research can be carried out on the adverse effects of long-term use of insects have on chicken and consumers.
iii. This research was carried out in a flagship area for insect-based feed. Further research can be carried out to capture more information on consumer preference and WTP for eggs produced from chicken fed on insect-based feed in other counties in Kenya.

iv. The above study provides insights that are confined by their narrow focus on an individual consumer rather than social, cultural and environmental contexts within which consumer decisions are made. Hence, the need for more research that should focus on diverse aspects that influence people's decisions and preferences for insects as feed and food.

REFERENCES

Adekunle, C. P., Akerele, D., Adekunle, A. K., & Amodemaja, T. S. (2016). Consumers' willingness to pay for organic leafy vegetables in Abeokuta southwest Nigeria: evidence from double bounded dichotomous choice approach. *Nigerian Journal of Agriculture, Food and Environment*, *12*(1), 17-23.

Agunbiade, J. A., Adeyemi, O. A., Ashiru, O. M., Awojobi, H. A., Taiwo, A. A., Oke, D. B., & Adekunmisi, A. A. (2007). Replacement of fish meal with maggot meal in cassava-based layers' diets. *The Journal of Poultry Science*, *44*(3), 278-282.

Al-Qazzaz, M. F. A., Ismail, D., Akit, H., & Idris, L. H. (2016). Effect of using insect larvae meal as a complete protein source on quality and productivity characteristics of laying hens. *Revista Brasileira de Zootecnia*, *45*, 518-523.

Alberini, A., & Cooper, J. (2000). *Applications of the contingent valuation method in developing countries: A survey* (Vol. 146). Food & Agriculture Org.

Alemu, M. H., Olsen, S. B., Vedel, S. E., Pambo, K. O., & Owino, V. O. (2015). *Consumer acceptance and willingness to pay for edible insects as food in Kenya: the case of white winged termites* (No. 2015/10). IFRO working paper.

Alemu, M. H., Olsen, S. B., Vedel, S. E., Kinyuru, J., & Pambo, K. O. (2016). *Integrating sensory evaluations in incentivized discrete choice experiments to assess consumer demand for cricket flour buns in Kenya* (No. 2016/02). IFRO Working Paper.

Alemu, M.H., Olsen, S.B., Vedel, S.E., Pambo, K.O., & Owino, V.O. (2017a). Combining product attributes with recommendation and shopping location attributes to assess consumer preferences for insect-based food products. *Food Quality and Preference*, 55: 45–57.

Alemu, M.H., Olsen, S.B., Vedel, S.E., Kinyuru, J.N. & Pambo, K.O. (2017b). Can insects increase food security in developing countries? an analysis of Kenyan consumer preferences and demand for cricket flour buns. *Food Security*, 9: 471-484.

Alfnes, F., & Rickertsen, K. (2011). Non-market valuation: experimental methods. The Oxford handbook of the economics of food consumption and policy, 215, 242.

Alphonce, R., & Alfnes, F. (2017). Eliciting consumer WTP for food characteristics in a developing context: Application of four valuation methods in an African market. *Journal of Agricultural Economics*, *68*(1), 123-142.

Angulo, A. M., & Gil, J. M. (2007). Risk perception and consumer willingness to pay for certified beef in Spain. *Food Quality and Preference*, *18*(8), 1106-1117.

Ankamah-Yeboah, I., Jacobsen, J. B., & Olsen, S. B. (2018). Innovating out of the fishmeal trap: The role of insect-based fish feed in consumers' preferences for fish attributes. *British Food Journal*, *120*(10), 2395-2410.

Abive-Bortsi, M., Baidoo, S. T., & Amiteye, S. (2022). Assessment of consumers' perception of chicken eggs consumption and associated health implications in the volta region of Ghana. *Nutrition and Metabolic Insights*, *15*, 11786388221118872.

Ayim-Akonor, M., & Akonor, P. T. (2014). Egg consumption: patterns, preferences and perceptions among consumers in Accra metropolitan area.

Barnkob, L. L., Argyraki, A., & Jakobsen, J. (2020). Naturally enhanced eggs as a source of vitamin D: A review. *Trends in Food Science & Technology*, *102*, 62-70.

Bazoche, P., & Poret, S. (2021). Acceptability of insects in animal feed: A survey of French consumers. *Journal of Consumer Behaviour*, *20*(2), 251-270.

Caruso, D., Devic, E., Subamia, I., Talamond, P. and Baras, E., 2014. Technical handbook of domestication and production of Diptera black soldier fly (BSF), Hermetia illucens, Stratiomyidae. IRD, Jakarta, Indonesia, 141 pp. Available at: http://tinyurl.com/n7t8bt4

Cherono, I., & Otieno, D. J. (2016). *Peri-urban food traders' preferences for open-air market design and management attributes in Nairobi, Kenya* (No. 310-2016-5410).

Chia, S. Y., Macharia, J., Diiro, G. M., Kassie, M., Ekesi, S., van Loon, J. J., & Tanga, C. M. (2020). Smallholder farmers' knowledge and willingness to pay for insect-based feeds in Kenya. *PLoS One*, *15*(3), e0230552.

Chukwuka, O. K., Okoli, I. C., Okeudo, N. J., Udedibie, A. B. I., Ogbuewu, I. P., Aladi, N. O., Iheshiulor, O.O., & Omede, A. A. (2011). Egg quality defects in poultry management and food safety. *Asian Journal of Agricultural Research*, *5*(1), 1-16.

Cochran, W. G. (1977). *Sampling techniques*. John Wiley & Sons.

Dao, A. N. C., Sankara, F., Pousga, S., Coulibaly, K., Nacoulma, J. P., Ouedraogo, S., Kenis M., & Somda, I. (2020). Traditional methods of harvesting termites used as poultry feed in Burkina Faso. *International Journal of Tropical Insect Science*, *40*(1), 109-118.

Diclaro II, J. W., & Kaufman, P. E. (2009). Black soldier fly Hermetia illucens Linnaeus (Insecta: Diptera: Stratiomyidae): EENY 461/IN830, 6/2009. *EDIS*, *2009*(7).

Diener, S., Zurbrügg, C., & Tockner, K. (2009). Conversion of organic material by black soldier fly larvae: establishing optimal feeding rates. *Waste Management & Research*, *27*(6), 603-610.

Domingues, C. H. D. F., Borges, J. A. R., Ruviaro, C. F., Gomes Freire Guidolin, D., & Rosa Mauad Carrijo, J. (2020). Understanding the factors influencing consumer willingness to accept the use of insects to feed poultry, cattle, pigs and fish in Brazil. *PloS one*, *15*(4), e0224059.

Dörper, A., Veldkamp, T., & Dicke, M. (2021). Use of black soldier fly and house fly in feed to promote sustainable poultry production. *Journal of Insects as Food and Feed*, *7*(5), 761-780.

Dortmans, B., Diener, S., Verstappen, B., & Zurbrügg, C. (2017). Black soldier fly biowaste processing. *A step-by step guide*.

Duinkerken, V., A. Huis, V., & T. Boekel, V. (2012). Insects as a sustainable feed ingredient in pig and poultry diets : a feasibility study = Insecten als duurzame diervoedergrondstof in varkens- en pluimveevoeders : een haalbaarheidsstudie. *Food Chemistry*, *50*(October), 192–195.

FAO. (2017a). FAO, The Future of Food and Agriculture: Trends and Challenges. http://www.fao.org/3/a-i6583e.pdf (accessed on January 8, 2018). In *Food and Agriculture Organization of the United Nations*.

FAO. (2017b). *Food and Agriculture Organization of the United Nations. Africa sustainable livestock 2050. Country brief Kenya, 2017.*

Greene, W. H. (2003). *Econometric analysis*. Pearson Education India.

Gido, O.E., Ayuya, I.O., Owuor, G. and Bokelmann, W. (2016). Consumer's Choice of Retail Outlets for African Indigenous Vegetables: Empirical Evidence Among Rural and Urban Households in Kenya. *Cogent Food and Agriculture*, 2(1):1-14.

Government Of Kenya (GOK). (2007). Ministry Of Planning and National Development. Kenya Vision 2030.

Government Of Kenya (GOK). (2019a). *Agricultural Sector Transformation and Growth strategy*. *Government of the Republic of Kenya* 1–216.

Government Of Kenya (GOK). (2019b). *Draft national livestock policy*. (February), 5–10.

Government of Kenya (GOK). (2010). 2009 Kenya National Population and Housing Census Volume 1A, Kenya National Bureau of Statistics, Nairobi.

Greiner, R., Bliemer, M., & Ballweg, J. (2014). Design considerations of a choice experiment to estimate likely participation by north Australian pastoralists in contractual biodiversity conservation. *Journal of choice modelling*, *10*, 34-45.

Gujarati, D. N. (2009). *Basic Econometrics*. Tata McGraw-Hill Education. New York.

Guyonnet, V. (2012, August). Eggs and egg products: Consumers' attitudes, perceptions and behaviours. In *Proceedings of the XXIV World's Poultry Congress* (pp. 1-10).

Halloran, A. (2015). *Regulating edible insects: the challenge of addressing food security , nature conservation , and the erosion of traditional.* (May).

Hanley, N., Wright, R., MacMillan, D., & Philip, L. (2001). Willingness to pay for the conservation and management of wild geese in Scotland.

Hasin, B. M., Ferdaus, A. J. M., Islam, M. A., Uddin, M. J., & Islam, M. S. (2006). Marigold and orange skin as egg yolk color promoting agents. *International Journal of Poultry Science*, *5*(10), 979-987.

Holt, S. H., Brand Miller, J. C., Petocz, P., & Farmakalidis, E. (1995). A satiety index of common foods. *European journal of clinical nutrition*, *49*(9), 675-690.

House, J. (2016). Consumer acceptance of insect-based foods in the Netherlands: Academic and commercial implications. Appetite, 107(September 2015), 47–58.

Jaafar, S.N., Lalp, P.E. and Nabal, M.M. (2011). Consumers' perceptions, attitudes and purchase intention towards private label food products in Malaysia. *Asian Journal of Business and Management Sciences*, 2(8): 73-90.

Joel, H. M. (2018). *Consumer willingness to pay for chicken meat derived from chicken fed on insect-based feed in Kenya* (Doctoral dissertation, University of Nairobi).

Kajale, D. & Becker, T. (2015). Factors influencing young consumers' acceptance of genetically modified food in India. *Journal of Food Products Marketing*, 21:461–481.

KALRO. (2015). *Annual Report*.

Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., & Mekuria, M. (2013). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. *Technological forecasting and social change*, *80*(3), 525-540.

Kenya Bureau of Standards (KEBS). (2017). Dried insect Products for compounding animal feeds. Kenyan Standard 2711:2012, ICS 65. 120

Kenya Bureau of Standards (KEBS). (2020). Production and handling of insects for food and feed: code of practice. Kenya Standard 2921:2017, ICS 67. 120

Kenya National Bureau of Statistics (KNBS). (2019). *2019 Kenya Population and Housing Census Volume I : Population By County and Sub-County*. Retrieved from http://www.knbs.or.ke

Kenya National Bureau of Statistics (KNBS). (2018). *Kenya national bureau of statistics the 2015/16 Kenya integrated household budget survey (KIHBS) Labour Force Basic Report*. Retrieved from http://www.knbs.or.ke

Khan, S. H. (2018). Recent advances in role of insects as alternative protein source in poultry nutrition. *Journal of Applied Animal Research*, *46*(1), 1144–1157.

Kimenju, S. C., & De Groote, H. (2008). Consumer willingness to pay for genetically modified food in Kenya. *Agricultural Economics*, *38*(1), 35–46.

Kinyuru, J. N., Kenji, G. M., & Njoroge, M. S. (2009). Process development, nutrition and sensory qualities of wheat buns enriched with edible termites (Macrotermes subhylanus) from Lake Victoria region, Kenya. *African Journal of Food, Agriculture, Nutrition and Development*, *9*(8).

Kinyuru, J., Ayieko, M., & Makkar, H. (2016). *Technical brief # 1: Insects as food and feed in Kenya – past , current and future perspectives*. (November).

KIPPRA. (2017). *Kenya Economic Report 2017*.

Konyole, S. O., Kinyuru, J. N., Owuor, B. O., Kenji, G. M., Onyango, C. A., Estambale, B. B., Friis, H., Roos, N. & Owino, V. O. (2012). Acceptability of amaranth grain-based nutritious complementary foods with dagaa fish (Rastrineobola argentea) and edible termites (Macrotermes subhylanus) compared to corn soy blend plus among young children/mothers in western Kenya. *Journal of Food Research*, 1(3): 11-120.

Kostecka, J., Konieczna, K., & Cunha, L. M. (2017). Evaluation of insect-based food acceptance by representatives of polish consumers in the context of natural resources processing retardation. *Journal of Ecological Engineering*, *18*(2), 166–174.

Lancaster, K. J. (1966). A New Approach to Consumer Theory. *The Journal of Political Economy*.74: 132-157.

Laureati, M., Jabes, D., Russo, V., & Pagliarini, E. (2013). Sustainability and organic production: How information influences consumer's expectation and preference for yogurt. *Food quality and preference*, *30*(1), 1-8.

Laureati, M., Proserpio, C., Jucker, C., & Savoldelli, S. (2016). New sustainable protein sources: consumers' willingness to adopt insects as feed and food. *Italian Journal of Food Science*, *28*(4).

Li, Q., Zheng, L., Cai, H., Garza, E., Yu, Z., & Zhou, S. (2011). From organic waste to biodiesel: Black soldier fly, Hermetia illucens, makes it feasible. *Fuel*, *90*(4), 1545-1548.

Li, Q., Zheng, L., Qiu, N., Cai, H., Tomberlin, J. K., & Yu, Z. (2011). Bioconversion of dairy manure by black soldier fly (Diptera: Stratiomyidae) for biodiesel and sugar production. *Waste management*, *31*(6), 1316-1320.

Lien, C. H., Wen, M. J., Huang, L. C., & Wu, K. L. (2015). Online hotel booking: The effects of brand image, price, trust and value on purchase intentions. *Asia Pacific Management Review*, *20*(4), 210-218.

Llagostera, P. F., Kallas, Z., Reig, L., & De Gea, D. A. (2019). The use of insect meal as a sustainable feeding alternative in aquaculture: Current situation, Spanish consumers' perceptions and willingness to pay. *Journal of Cleaner Production*, *229*, 10-21.

Louviere, J. J., Hensher, D. A., & Swait, J. D. (2000). *Stated choice methods: analysis and applications*. Cambridge university press.

Makkar, H. P. S., Tran, G., Heuzé, V., & Ankers, P. (2014). State-of-the-art on use of insects as animal feed. *Animal Feed Science and Technology*, *197*, 1–33.

Manski, C. F. (1977). The structure of random utility models. *Theory and decision*, *8*(3), 229.

Marono, S., Loponte, R., Lombardi, P., Vassalotti, G., Pero, M. E., Russo, F., Gasco, L., Parisi, G., Piccolo, G., Nizza,S., Di Meo, C., Attia, Y. A., & Bovera, F. (2017). Productive performance and blood profiles of laying hens fed Hermetia illucens larvae meal as total replacement of soybean meal from 24 to 45 weeks of age. *Poultry Science*, *96*(6), 1783-1790.

Maurer, V., Holinger, M., Amsler, Z., Früh, B., Wohlfahrt, J., Stamer, A., & Leiber, F. (2016). Replacement of soybean cake by Hermetia illucens meal in diets for layers. *Journal of Insects as Food and Feed*, *2*(2), 83–90.

McFadden, D. (1974), "Conditional Logit Analysis of Qualitative Choice Behavior," in P. Zarembka (editor), Frontiers in Econometrics, New York: Academic Press.

McFadden, D., & Train, K. (2000). Mixed MNL models for discrete response. *Journal of applied Econometrics*, *15*(5), 447-470.

Miranda, C. D., Cammack, J. A., & Tomberlin, J. K. (2019). Life-history traits of the black soldier fly, hermetia illucens (L.) (diptera: Stratiomyidae), reared on three manure types. *Animals*, *9*(5).

Mwaniki, Z., Neijat, M., & Kiarie, E. (2018). Egg production and quality responses of adding up to 7.5% defatted black soldier fly larvae meal in a corn–soybean meal diet fed to Shaver White Leghorns from wk 19 to 27 of age. *Poultry science*, *97*(8), 2829-2835.

Naranjo-Guevara, N., Fanter, M., Conconi, A. M., & Floto-Stammen, S. (2021). Consumer acceptance among Dutch and German students of insects in feed and food. *Food Science & Nutrition*, *9*(1), 414-428.

Netherlands African Business Council. (2015). Factsheet Kenya poultry, meat & processing sector contact information. *Business, Netherlands-African*, 1–3.

Nyakeri, E. M., Ogola, H. J., Ayieko, M. A., & Amimo, F. A. (2017). An open system for farming black soldier fly larvae as a source of proteins for small scale poultry and fish production. *Journal of Insects as Food and Feed*, *3*(1), 51–56.

Nyaga P. (2007). Poultry Sector Country Review. *FAO Animal production and health division, emergency centre for transboundary animal diseases, socio economic production and biodiversity unit, FAO.*

Onsongo, V. O. (2017). *Performance and meat quality of broiler chicken fed diets enriched with black soldier fly (Hermetia illucens) larvae meal* (Doctoral dissertation, University of Nairobi).

Omiti, J. M., & Okuthe, S. O. (2009). An overview of the poultry sector and status of highly pathongenic avian influenza (HPAI) in Kenya - Background paper. Collaborative research on pro-poor HPAI risk reduction, Africa/Indonesia Team Working Paper No. 4. Washington DC, United States of Ameri. *Collaborative Research on Pro-Poor HPAI Risk Reduction*, 1–107.

Plain, C., & Station, E. (1977). *Newton et al., 1977*. *44*(3).

PROteINSECT. (2016). *Insect Protein – Feed for the Future Addressing the need for feeds*.

Randall, A., Ives, B., & Eastman, C. (1974). Bidding games for valuation of aesthetic environmental improvements. *Journal of environmental Economics and Management*, *1*(2), 132-149.

Ravindran, V. (2013). Poultry Feed Availability and Nutrition in Developing Countries: Main Ingredients used in Poultry Feed Formulation. *Poultry Development Review*, *2*(10), 694–695.

Roma, R., Ottomano Palmisano, G., & De Boni, A. (2020). Insects as novel food: A consumer attitude analysis through the dominance-based rough set approach. *Foods*, *9*(4), 387.

Rondoni, A., Asioli, D., & Millan, E. (2020). Consumer behaviour, perceptions, and preferences towards eggs: A review of the literature and discussion of industry implications. *Trends in Food Science & Technology*, *106*, 391-401.

Rumpold, B. A., & Schlüter, O. K. (2013). Potential and challenges of insects as an innovative source for food and feed production. *Innovative Food Science & Emerging Technologies*, *17*, 1-11.

Selaledi, L., Hassan, Z., Manyelo, T. G., & Mabelebele, M. (2021). Insects' production, consumption, policy, and sustainability: what have we learned from the indigenous knowledge systems?. *Insects*, *12*(5), 432.

Sebatta, C., Ssepuuya, G., Sikahwa, E., Mugisha, J., Diiro, G., Sengendo, M., Fuuna P., & Nakimbugwe, D. (2018). Farmers' acceptance of insects as an alternative protein source in poultry feeds. *International Journal of Agricultural Research, Innovation and Technology (IJARIT)*, *8*(2355-2020-1652), 32-41.

Senbeta, E., Zekele, N., & Molla, Y. (2015). Attitudes and perceptions of consumers to chicken egg attributes in Eastern Ethiopia. *Journal of animal production advances*, *5*(6), 705-710.

Shaw, M., Nielson, H., & Rose, M. (2019). *Poultry sector study*. (March), 1–99.

Shumo, M., Osuga, I. M., Khamis, F. M., Tanga, C. M., Fiaboe, K. K., Subramanian, S., Ekesi, S., Van Huis, A., & Borgemeister, C. (2019). The nutritive value of black soldier fly larvae reared on common organic waste streams in Kenya. *Scientific reports*, *9*(1), 10110.

Silva, L. M. D., Bitencourt, C. C., Faccin, K., & Iakovleva, T. (2019). The role of stakeholders in the context of responsible innovation: A meta-synthesis. *Sustainability*, *11*(6), 1766.

Sogari, G. (2015). Entomophagy and Italian consumers: An exploratory analysis. *Progress in Nutrition*, *17*(4), 311-316.

Spartano, S., & Grasso, S. (2021). Consumers' perspectives on eggs from insect-fed hens: a UK focus group study. *Foods*, *10*(2), 420.

Ssepuuya, G., Namulawa, V., Mbabazi, D., Mugerwa, S., Fuuna, P., Nampijja, Z., Ekesi, S., Fiaboe, K. K. M., & Nakimbugwe, D. (2017). Use of insects for fish and poultry compound feed in sub-Saharan Africa - A systematic review. *Journal of Insects as Food and Feed*, *3*(4), 289–302.

Szendrő, K., Nagy, M. Z., & Tóth, K. (2020). Consumer acceptance of meat from animals reared on insect meal as feed. *Animals*, *10*(8), 1312.

Tan, H. S. G., Fischer, A. R., Tinchan, P., Stieger, M., Steenbekkers, L. P. A., & van Trijp, H. C. (2015). Insects as food: Exploring cultural exposure and individual experience as determinants of acceptance. *Food quality and preference*, *42*, 78-89.

The World Bank (2015). *Gender in Climate- Smart Agriculture*. 96.

Tonsor, G. T., Olynk, N., & Wolf, C. (2009). Consumer preferences for animal welfare attributes: The case of gestation crates. *Journal of Agricultural and Applied Economics*, *41*(3), 713-730.

UNEP. (2018). Africa Waste Management Outlook.

Van Den Brandt, P. A. (2019). Red meat, processed meat, and other dietary protein sources and risk of overall and cause-specific mortality in The Netherlands cohort study. *European journal of epidemiology*, *34*(4), 351-369.

Van der Fels-Klerx, H. J., Camenzuli, L., Belluco, S., Meijer, N., & Ricci, A. (2018). Food safety issues related to uses of insects for feeds and foods. *Comprehensive Reviews in Food Science and Food Safety*, *17*(5), 1172-1183.

Van Huis, A., Dicke, M., & van Loon, J. J. A. (2015). Insects to feed the world. *Journal of Insects as Food and Feed*, *1*(1), 3–5.

Van Huis, van Itterbeeck, J., Klunder, H., Mertens, E., Halloran, A., Muir, G., & Vantomme, P. (2013). Future prospects for food and feed security. In *Food and Agriculture Organization of the United Nations* (Vol. 171).

Veldkamp, T., van Duinkerken, G., van Huis, A., Ottevanger, E., Bosch, G., & van Boekel, T. (2012). Insects as a sustainable feed ingredient in pig and poultry diets: a feasibility study = Insecten als duurzame diervoedergrondstof in varkens- en pluimveevoeders : een haalbaarheidsstudie. *Food Chemistry*, *50*(Ii), 192–195.

Verbeke, W., Spranghers, T., De Clercq, P., De Smet, S., Sas, B., & Eeckhout, M. (2015). Insects in animal feed: Acceptance and its determinants among farmers, agriculture sector stakeholders and citizens. *Animal Feed Science and Technology*, *204*, 72–87.

Wang, Y. S., & Shelomi, M. (2017). Review of black soldier fly (Hermetia illucens) as animal feed and human food. *Foods*, *6*(10), 91.

Wilson, D. C., Rodic, L., Modak, P., Soos, R., Carpintero, A., Velis, K., Iyer, M., & Simonett, O. (2015). *Global waste management outlook*. UNEP.

Wooldridge. (2013). Introductory Econometrics. *Introductory Econometrics*.

Yong, A. G. and Pearce, S. (2013). A Beginner's Guide to Factor Analysis: Focusing on Exploratory Factor Analysis. *Tutorials In Quantitative Methods for Psychology*, 9(2): 79-94.

Zamasiya, B., Nyikahadzoi, K. and Mukamuri, B.B. (2017). Factors influencing smallholder farmers' behavioral intention towards adaptation to climate change in

transitional climatic zones: A case study of Hwedza in Zimbabwe. *Journal of Environmental Management*, 198: 233-239.

Zotte, A. D., Singh, Y., Michiels, J., & Cullere, M. (2019). Black soldier fly (Hermetia illucens) as dietary source for laying quails: Live performance, and egg physico-chemical quality, sensory profile and storage stability. *Animals*, *9*(3), 1–20.

APPENDICES

Appendix A: Consumer Survey Questionnaire

Questionnaire No…….

Dear sir/ madam,

HALLO, my name is _____and I am part of a team from Egerton University and ICIPE, who are studying aspects to do with eggs produced from chicken fed on black soldier fly larvae-based feed consumption with emphasis on consumers' perception, factors influencing acceptability of the eggs and willingness to pay for their attributes. Your participation in answering these questions is highly appreciated. Your responses will be **COMPLETELY CONFIDENTIAL** and used solely for research purposes together with other 196 consumers. If you indicate your voluntary consent by participating in this interview, may we begin? If you have any questions or comments about this survey, you may contact survey supervisor through the following address: **Colleta Nabwile Khaemba Department of Agricultural Economics and Agribusiness Management, Egerton University, P.O. Box 536, Egerton. Cell phone:**
0715648516. Email address: nabwilekhaemba@gmail.com.

County: _____ Sub county: _____

Ward: _____ Village: _____

1. Name of enumerator ……. Date…….

2. Name of respondent ……Mobile No……

Consumer ID:

Place of interview…….

(Kiosk, market, construction site)

SECTION A: SOCIOECONOMIC CHARACTERRISTICS OF THE PURCHASE AND CONSUMPTION DECISION MAKER.

Please tick (√) the appropriate choice

1. How old are you (in years)? …….

2. Gender: 1=Male []; 0= Female []

3. What is your **education level**? (*Tick appropriately)* 1= Not gone to school []; 2= primary

   []; 3= secondary []; 4= college []; 5= university []

4. What is your marital status? 1= Married []; 2=Single []

5. What is the size of your household? ……..

6. What is your household type? 1= Male headed []; 2= Female headed []

7. How many of the children in your household are below 5years? .....

8. What is your main occupation?

9. Are you involved in any other activities that are on-farm? 1=Yes [], 0=No []

10. In which category do you estimate your total household income in KES/month? (Farm, employment, business income, pensions and remittances from elsewhere from all working members) .....

    : HOUSEHOLD INCOME CATEGORIES

    1=<10000

    2=10001-20,000

    3=20001-30000

    4=30001-40000

    5=> 40000

11. Do you consume eggs?1=Yes [],0=No []

12. What type of eggs do you prefer most? 1= Free range (kienyeji) []; 2= Conventional(grade) []

13. For how long have you been consuming eggs? .....

14. How much do you spend on the following in a month on the following items?

Item	Estimated monthly expenditure
Food	
Rent	
Clothing	
Medicare	

15. How many times do you buy eggs in a month?
16. What proportion of spending is on eggs?

SECTION B: INSTITUTIONAL CHARACTERISTICS.

1. Where do you buy eggs?1= Market [] 2= kiosk [] 3=Supermarket []
2. How long does it take you walking to where you buy eggs? (Minutes).....
3. From whom do you get information on the nutritional and food security? 1=Nutritional / Health officer [], 2=Friends and Relatives [], 3=Media [], 4=Radio, TV, newspaper 6=Others(specify)

   …….
4. Distance to the nearest information source office (from question 3 above) from residence

……..……
5. Do you belong to any group that is concerned with food nutrition matters?1=Yes [], 0=No []
6. Which information technology do you own? Radio [] TV [] Phone []
7. Main purpose of the technology, whether for agricultural information or other…….
8. Do you transfer the technology or information to fellow consumers and how many?.....
   .....

SECTION C: CONSUMER PERCEPTION ON USE OF INSECT AS FEED

1. Do you know what layers are fed on? 1=yes []; 2= No []
2. If YES, can you mention some of the feeds you know?
3. Are you aware that layers can be fed on the following protein sources?

Fish meal (Omena) 1= Yes []; 2= No []

Soya bean meal 1= Yes []; 2= No []

Insects (black soldier fly, termites, housefly) 1= Yes []; 2= No []

There are plans to use insects (black soldier fly) as a source of protein in chicken feed in Kenya. The eggs produced are expected to be more nutritious, bigger in size and bigger yolk than normal eggs. I'm going to read you some statements about your view on your consumption of eggs derived from black soldier fly based feed. Kindly indicate how you view or see eggs produced from chicken fed on black soldier fly? To show your views tick only once against each statement where 1=strongly disagree (SD); 2=disagree (D); 3=undecided (U); 4=agree (A); 5=strongly agree (SA) to show the extent of your agreement with the statement.

	Perception statement	SD	D	U	A	SA
1	I have adequate knowledge on feeds fed to chicken for egg production					
2	I take into consideration what layer chicken are fed on before I buy eggs					
3	I am bothered about what the chicken were fed on before I buy eggs					
4	Eggs produced from chicken fed on black soldier fly larvae meal are the same as eggs produced from chicken fed on conventional feed					
5	Eggs produced from chicken fed on black soldier fly larvae meal are same as fish and meat					
6	I would buy eggs produced from chicken fed on black soldier fly larvae meal regardless of the price					

7	Eggs produced from chicken fed on black soldier fly larvae meal are hygienic					
8	Consuming eggs produced from black soldier fly larvae meal is healthy					
9	I would buy eggs produced from chicken fed on black soldier fly larvae meal only if recommended by health authorities					
10	Eggs produced from chicken fed on black soldier fly larvae meal have chemical residue					
11	Consuming eggs produced from chicken fed on black soldier fly larvae meal is environmentally friendly					
12	Eggs produced from chicken fed on black soldier fly larvae meal are rich in nutrients					
13	Eggs produced from chicken fed on black soldier fly larvae meal are medicinal					
14	Eggs produced from chicken fed on black soldier fly larvae meal are a luxury					
15	Use of insects as chicken feed will lower the price of eggs					
16	Use of black soldier fly larvae as chicken feed goes against my religious beliefs					
17	Use of black soldier fly larvae as chicken feed goes against my culture					
18	Eggs produced from black soldier fly should be labeled					

EGGS ATTRIBUTES RANKING.

When buying eggs are the following characteristics important in your decision to buy?

Characteristics	**Very important**	**Important**	**Neutral**	**Not important**	**Not very important**
Price					
Type of feed					
Size					
Yolk colour					

SECTION D: WILLINGNESS TO PAY FOR ATTRIBUTES OF EGGS PRODUCED FROM CHICKEN FED ON BLACK SOLDIER FLY LARVAE MEAL

There are plans to use insects (black soldier fly) as a source of protein in chicken feed in Kenya. The eggs produced are expected to be more nutritious, bigger in size and bigger yolk than normal eggs. Suppose these eggs were introduced in the market today and have the following profiles:

Would you be willing to buy? (Yes/no)

This next part will have 8 profiles. These profiles have egg attributes that are hypothetical. Please check only one box.

Choice set 1

Egg characteristics	**Egg 1**	**Egg 2**	**None**
Size	Small	Large	
Yolk colour	Pale yellow	Golden Yellow	
Feed type	Black soldier fly larvae	Conventional	
Price	12	10	

Choice set 2

Egg characteristics	**Egg 1**	**Egg 2**	**None**
Size	Medium	Small	
Yolk colour	Golden yellow	Pale yellow	
Feed type	Conventional	Black soldier fly larvae	
Price	12	10	

Choice set 3

Egg characteristics	Egg 1	Egg 2	None
Size	Medium	Small	
Yolk colour	Golden yellow	Golden yellow	
Feed type	Conventional	Black soldier fly larvae	
Price	14	10	

Choice set 4

Egg characteristics	**Egg 1**	**Egg 2**	**None**
Size	Large	Small	
Yolk colour	Pale yellow	Golden yellow	
Feed type	Conventional	Black soldier fly larvae	
Price	14	12	

Choice set 5

Egg characteristics	**Egg 1**	**Egg 2**	**None**
Size	Medium	Medium	
Yolk colour	Golden yellow	Pale yellow	
Feed type	Black soldier fly larvae	Conventional	
Price	14	10	

Choice set 6

Egg characteristics	**Egg 1**	**Egg 2**	**None**
Size	Large	Small	
Yolk colour	Pale yellow	Pale yellow	
Feed type	Conventional	Black soldier fly larvae	
Price	12	10	

Choice set 7

Egg characteristics	**Egg 1**	**Egg 2**	**None**
Size	Medium	Large	
Yolk colour	Golden yellow	Pale yellow	
Feed type	Black soldier fly larvae	Conventional	
Price	10	12	

Choice set 8

Egg characteristics	**Egg 1**	**Egg 2**	**None**
Size	Large	Small	
Yolk colour	Pale yellow	Pale yellow	
Feed type	Conventional	Conventional	
Price	12	14	

Question (Instructions)	**Response**	
How sure are you about the egg choices you made?	Very sure[] Sure[] Probably sure[] not sure	
Were you considering and comparing attributes before you made a choice?	Yes	No
Are there specific attributes that you were looking for in each choice option before you made each decision?	Yes	No
If yes, specify the selected attributes.	Size, price, yolk colour, type of feed used	

THANK YOU FOR YOUR COOPERATION

Appendix B: Pair Wise Correlation Stata Output

	gender	income	information	group	awareness	market	kiosk
gender	1						
income	0.2339	1					
information	-0.1909	-0.0154	1				
group	-0.1414	-0.1041	0.315	1			
awareness	-0.0082	-0.0187	0.0936	0.0445	1		
market	-0.0915	-0.058	-0.0455	-0.0768	-0.055	1	
kiosk	0.0433	-0.044	-0.0045	0.038	0.0288	-0.4054	1
supermarket	0.0141	0.1216	-0.008	0.0799	0.0285	-0.1305	0.0173
farmer	0.0108	0.0162	0.004	0.0543	0.0562	-0.199	-0.3173
credit	0.0409	0.1101	-0.0382	-0.0252	0.0477	0.0173	-0.0105
offfarmincome	-0.1586	-0.0784	0.0436	0.0264	0.0543	0.2456	-0.3304

	supermarket	farmer	credit	offfarmincome
supermarket	1			
farmer	-0.1203	1		
credit	-0.0115	0.024	1	
offfarmincome	-0.0924	0.2117	-0.0409	1

Appendix C: Publication abstract

PROCESSING AND PRODUCTS

Consumers' perception towards eggs from laying hens fed commercial black soldier fly (*Hermetia illucens*) larvae meal-based feeds

Colleta Nabwile Khaemba [*,†,1] Michael Mukembo Kidoido [†] George Owuor,[*] and Chrysantus Mbi Tanga [†]

[*]*Department of Agricultural Economics and Agribusiness Management, Egerton University, P.O. Box 536-20115, Njoro, Kenya; and* [†]*International Centre of Insect Physiology and Ecology (icipe), P.O. Box 30772-00100, Nairobi, Kenya*

ABSTRACT Increased demand for animal protein has motivated the search for more efficient livestock production systems. In recent years, there has been growing interest to incorporate insect meal as an alternative source of protein to fish/soybean meal in chicken feed for improved nutrition, sustainability, and animal welfare benefits. Black soldier fly larval (**BSFL**)-based feeds has been shown to increase egg production in a cost-effective manner. However, poultry consumers perception towards the consumption of eggs from layers fed diet integrated with BSFL-based meal have received limited research attention. This study evaluates consumers' perception towards eggs from hens fed BSFL-based diets and socioeconomic factors influencing the conceived perceptions. The study adopted an exploratory factor analysis (**EFA**) and binary logit regression models to establish perceptions of 200 consumers in Kiambu County, Kenya. Our results revealed that 65% of the consumers were aware of the benefits of integrating insect protein in poultry feed. Over 70% of respondents showed preference and willingness to consume egg products from hens fed diets with BSFL-based feeds. The EFA identified perceived benefits, ethics and traceability as the key aspects that influence consumer intention to consume eggs. Binary logit model revealed that consumer characteristics such as household size, gender, awareness of insects as feed, off-farm income, household income, nature of buying place, and access to credit were important factors driving consumers perceptions. Our findings provide insight into the market perception and potential of eggs from laying hens fed BSFL-based feeds. Our findings demonstrated that increased awareness creation and evidence-based demonstration on the benefits of BSFL-based feed in poultry production would improve consumer perception and foster uptake of this rapidly growing and emerging technology. This work contributes to the limited knowledge on BSFL-based feeds and paves way for further linkages between farmers, public private partners, policy makers, and consumers.

Key words: black soldier fly larvae meal-based feeds, chicken eggs, consumer perception, sustainability, food security

2022 Poultry Science 101:101645
https://doi.org/10.1016/j.psj.2021.101645

INTRODUCTION

The increasing global population has resulted in higher demand for protein rich foods specifically animal proteins, consequently requiring an increase in their production (FAO, 2017). This requires increased productivity of the livestock subsector which plays a vital role in the Kenyan economy accounting for about 12% of the national GDP (2018). Among the important subsectors of the Kenyan livestock sector is the poultry subsector accounting for about 30% of the sector's GDP (Netherlands Africa Business Council NABC, 2019). The poultry subsector contributes to incomes in rural and urban households and improves nutrition by the provision of meat and eggs as there is a growing demand for poultry products (GOK, 2019).

The growth of the poultry subsector has been slow but has steadily increased over the years (Kenya Bureau of Standards KEBS, 2017). The slow growth is attributed to high cost of production mainly due to feed materials used and lack of quality feed (Shaw, et al., 2019). The commercial feeds sector uses conventional protein sources (soy bean and fish meal) which account for 60 to 70% of production costs (Veldkamp and Bosch, 2015; Ravindran, 2013). The use of conventional proteins in animal

Received July 21, 2021.
Accepted December 1, 2021.

[1]Corresponding author: ckhaemba@icipe.org