CONSUMERS AND PRODUCERS' ACCEPTABILITY, ATTITUDES AND PERCEPTIONS OF BROILER CHICKEN REARED ON BLACK SOLDIER FLY LARVAE FED WITH FAECAL SLUDGE IN KENYA

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A Research Thesis Submitted in Partial Fulfilment of the Requirements for Conferment of the Degree of Master of Science in Sanitation of Meru University of Science and Technology

2025

DECLARATION

This thesis is my original work and has not been presented for a degree award in any other Institution.

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DECLARATION BY SUPERVISORS

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DEDICATION

This work is dedicated to my parents, Mr. Daniel Kobia and Mrs. Hellen Kobia, for being my fountain source of inspiration and continuous encouragement.

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ABBREVIATIONS

ANOVA	Analysis of Variance
BSF	Black Soldier Fly
BSFL	Black Soldier Fly Larvae
FGD	Focus Group Discussion
FS	Faecal Sludge
FSM	Faecal Sludge Management
MIRERC	Meru University OF Science and Technology institutional Research Ethics Review Committee
MUST	Meru University of Science and Technology
NACOSTI	National Commission for Science, Technology and Innovation
OSS	Onsite Sanitation
UN	United Nations
SDP	Sanitation Derived Products
SPSS	Statistical Package for the Social Sciences
SRI	Sanitation Research Institute
TML	Tenebrio Molitor Larvae

ABSTRACT

The Sustainable Development Goals agenda two and 6.2 focus on achievement of zero hunger and attainment of safely managed sanitation by 2030. Yet, many developing countries, including Kenya, remain off track, with populations still vulnerable to nutrition and sanitation-related challenges. Black soldier fly larvae (BSFL) technology offers an innovative solution by converting organic and faecal waste into nutrient-rich protein and fat. These compounds can substitute soybean and fishmeal in animal feeds and potentially human food, addressing both food insecurity and waste management. However, the acceptability of BSFL-derived products among consumers and producers remains uncertain. This study examined perceptions and attitudes of consumers toward broiler chicken fed on BSFL-based diets, explored producers' views on rearing and consuming such chicken, and compared sensory evaluation results between BSFL-fed and conventionally fed broilers. A convergent mixed-methods design was applied, combining structured questionnaires, focus group discussions, and laboratory-based sensory evaluations. 150 one-day-old broiler chicks were reared in different pods (2m by 2m) in triplicate pens. At 10 weeks, subjected to 24-hour feed withdrawal, the chickens were slaughtered inclusively with veterinary officers overseeing inspections. Breast muscles were then wrapped in foil, labelled and cooked in a zip-loc bag at 78°C for 15 minutes in a water bath, with temperature monitored by a thermometer. After cooling samples were cut into uniform 1cm² cubes, coded and presented to panelists for evaluation in equipped individual booths. Data was analyzed using SPSS v26, with qualitative narratives thematically examined. Results showed significant sensory differences in broiler meat characteristics such as colour and texture across dietary treatments. The findings showed a high overall satisfaction with BSF fed chickens by panelists who highlighted positive attributes like improved taste and overall eating experience. Among producers, 85% did not view protein substitution as problematic, while 73% preferred BSFL-fed poultry, citing cost-effectiveness and natural production. On the consumer side, 93% were open to eating meat produced using technology, with 73% emphasizing taste as a key determinant of acceptability. The findings suggest strong potential for BSFL integration into poultry production, with positive implications for food security, sustainable agriculture, and circular sanitation economies in Kenya. The study recommended the need for awareness to poultry consumers and producers to encourage adoption of BSFL-based feeds. The study also recommended exploration of new marketing strategies and distribution channels to expand the market for the products.

CHAPTER ONE: INTRODUCTION

To provide a clear understanding of the study, this chapter begins with a discussion of the background information that situates the research within its broader context. It then highlights the research gap under investigation, outlines the objectives and research questions, and explains the justification for undertaking the study. The chapter further clarifies the underlying assumptions and specifies the delimitations that set the scope of the research, while also acknowledging the limitations that may affect its outcomes. Collectively, these components establish the foundation upon which the study is built and guide the analysis presented in the subsequent chapters

1.1 Background Information

Universal access to safe sanitation is fundamental for good hygiene, health and community well-being. However, the development of sanitation systems including latrines, toilets and waste management facilities has impacted a major challenge on sanitation delivery chain. A report by UN (2015) showed that 4.5 billion people lack access to safely managed sanitation worldwide and among them 892 million people practice open defecation (United Nation, 2018). In Africa, more than 60% of the population lack access to improved sanitation, therefore depend on rudimentary sanitation facilities that can expose faecal into the environment causing environmental contamination (Lalander *et al.,* 2019).

Previous efforts towards providing safe sanitation only focused on toilet provision leaving out the entire sanitation delivery chain and how the products can be relied upon as useful (Matheka *et al.,* 2021). Universal access to safe sanitation can only be realized if focus expands to full cycle sanitation comprising of access, containment, emptying, transportation, treatment and reuse of faeces (Devaraj *et al.,* 2021). Sewer systems have been the norm for

waste management in developing countries. For example, only 12% of the Kenyan population have access to sewer services (Riungu, 2021). However, the system is only appropriate in well planned areas and is dependent on large water quantities, large capital and maintenance cost which make conventional sewer system not practical in developing countries (Strande, 2014). The situation has left the majority of people dependent on onsite sanitation globally as shown in a report by Harada *et al*. (2016) where 2.7 billion people depend on onsite sanitation facilities for management of faecal waste globally.

Onsite facilities such as container-based sanitation are designed to reduce moisture content on the faecal sludge by separating the urine and faeces. Faecal waste accumulated onsite require to be periodically treated before disposal or reuse ((Taweesan *et al.,* 2015;Chandana & Rao, 2022). Faecal matter from onsite sanitation systems has been noted as an important resource (feed) for certain 'wonder' insects. Such insects can act upon the faecal matter and reduce its pathogen nature (Matheka *et al.,* 2021) thus minimizing the costs of treatment.

Recent developments have seen an emergence of various circular economy resource-oriented approaches such as composting, vermicomposting and black soldier fly technology being investigated and promoted to ease waste management challenges (Wang & Shelomi, 2017). Black soldier fly larvae (BSFL) technology is one of the technological advancements that has been incorporated into the management of faecal sludge through treatment and upcycle of the organic waste into agricultural products. BSFL is a technology that intervened to respond to inadequate access to safe sanitation and management of waste. It has been widely used in developing agricultural inputs embodying the insect-based protein for feeding animals (Shelomi, 2020) and poultry and manufacturing organic fertilizer (Sutradhar *et al.,* 2021).

Among the technologies discussed by McConville *et al.,* (2020), BSF is a biological treatment technology that relies on the natural growing cycle of the BSF. As the larvae feed, a portion of the organic material is transformed into larval biomass. Faecal sludge management with the larvae of Black Soldier fly reported a reduction in the concentration of pathogenic micro-organisms in human feces (Lalander *et al.,* 2019). The insect voracious feeding rate significantly allows them to shred and consume different kinds of organic matter reducing their volume and concurrently producing valuable nutritious products for animal and human feed (Kim *et al.,* 2021).

According to studies, using insects as feed reduces feed costs and provides a substantial supply of protein (Van Huis *et al.,* 2013). Stakeholders have offered advice on how to best incorporate insects into the diet. In the past, insects have been fed directly to fish and poultry (Van Huis *et al.,* 2015). Tests on a number of bug species have revealed higher protein contents than those of traditional protein sources. The prevalent species comprise the following: the yellow mealworm beetle (Tenebrio Molitor) and the alphitobium (Alphitobius diaperinus), the black soldier fly (*Hermetia illucens*) and the common fly (Musca domestica), the silkworm (Bombyx mori), the tropical cricket (Gryllodes sigillatus), and the silent cricket (Gryllus assimilis) (Duinkerken *et al*., 2012).

Black soldier fly larvae are one of the newest and most promising protein sources available. They are also inexpensive, can be produced year-round, and can be used to manage trash (Diener *et al.,* 2009; Dortmans *et al.,* 2017). Black soldier fly larvae require less room for production and can be raised on a variety of wastes, allowing families to dispose of less garbage overall and lowering their carbon footprint (Nyakeri *et al.,* 2017). The larvae of black soldier flies have high levels of dry matter proteins (40–45%), amino acids,

carbohydrates, lipids (30-35%), minerals, and several important vitamins (5%). The treatment residue, comprised of larval droppings and ungraded material, appears as a compost-like material that can be used as a soil conditioner (Dortmans *et al.,* 2017;Nyakeri *et al.,* 2017). These qualities are crucial as an addition to chicken feed. Consequently, it is anticipated that chicken fed on black soldier fly larvae-based feed will have higher nutritional value than chickens fed on regular diet. Nevertheless, there are certain possible hazards connected to using insects as food, like perception and market acceptability (Duinkerken *et al.,* 2012). Additional research is required as these issues have not been sufficiently examined.

Consumption of insect- based foods by people is called Entomophagy. Entomophagy has been practiced in many communities in the Southeast Asia, Latin America and Africa (Gmuer *et al.,* 2016). Human consumption of insects can be either direct as a whole or incorporated into other meals. Several studies in Western Countries showed that acceptance of insect consumption is lower in these regions due to lack of sensory appeal, perceptions and attitudes, unfamiliarity, poor image, disgust and low availability (Ruby *et al.,* 2015). Recent research has shown that incorporation of insects into familiar foods can increase appeal (Gmuer *et al.,* 2016).

A study by Higa et al., (2021) that examined the perception of American's attitude towards BSF-based foods showed that participants were willing to consume BSF in some form. However, the study showed that the participants preferred the meals inform of flour or rendered fat than with visible insect traces. Disgust and perception on the product's benefits could predict acceptability of insect-based products. Such was the case in Thailand as reported in a study by Tan et al., (2015) that traced the socio-cultural factors affecting the

acceptance of insect foods, that mealworms were rejected as food due to its association with decaying matter. Researchers have not only pointed to the perceptions on direct consumption of insects as food but have also highlighted people's reaction on indirect feeding of the products. A study in Kenya by Khaemba et al. (2022) established that consumers' perception for eggs from chicken reared on BSFL meal was negative for some people and was determined by awareness of the type of feeds that the chicken was fed on and benefits of the feeds. The studies demonstrated the need to educate consumers on benefits of insect-based meals to enhance acceptance and consumption willingness.

The consumption willingness and acceptance of products derived from BFSL fed chicken and fish has been a concern in European markets (Biasato et al., 2019; Domingues et al., 2020; Szendro et al., 2020). However, culture and perception regarding health aspects and nutrition of the products are ranked among the reasons that affect acceptance. A study in China and Germany by Hartmann et al., (2015) that explored the cultural issues surrounding insect products consumption established that neophobia (fear of eating insects), social acceptance and taste expectations were among the higher predators of consumer willingness to consume insects in both countries. Given the need for more cost-effective proteins in poultry feeds, it is evident that utilization of insect fed products has been implemented in developed countries. However, there is little research on acceptance of BSFL-fed chicken by consumers and producers in developing countries. Therefore, there is need to assess the perception and attitudes of consumers and producers towards eating broiler chicken whose protein feed has been substituted with BSF in Kenya.

Studies by Chia et al., (2020); Kawasaki *et al*., (2019); Dorper *et al*., (2021) have focused on the partial replacement of fishmeal and soybean meal by insects on poultry performance.

However, the sector is still in its infancy as several uncertainties remain unaddressed (Dorper *et al.,* 2021). BSFL are suitable sources of protein for poultry. Insects have been favoured by consumers as food and feed. In Kenya, rural communities traditionally consume grasshoppers, crickets, black ants, and termites as part of their diet (Kinyuru *et al.,* 2016). Since they have been shown to be a good source of protein, insects are also inherently included in the meals of free-range chickens (Zotte *et al.,* 2019). Nonetheless, commercially raised chickens rely on prepackaged meals. This prompted studies on insect-based feed, which have had promising results and will soon be used by smallholder farmers. Analyzing the usage of insect-based feed in chicken production is crucial since it offers solutions aimed at reducing feed costs and improving product quality. However, the effect of live Black soldier fly supplementation on chicken broilers performance and behaviors has not been quantified (Cullere *et al.,* 2018) due to limited knowledge about the sensory traits of the derived sanitation products from both consumers and producers. Therefore, the need to explore perceptions, attitudes and sensory evaluation tests on broiler chicken whose protein quality was substituted with BSF feed in comparison to the conventional fed chicken to check perceptions and attitudes and consumer acceptability of faecal sludge derived products in Kenya.

1.2 Problem Statement

The acceptability, attitudes and perceptions of consumers and producers towards eating and rearing broiler chicken reared on Black Soldier Fly Larvae (BSFL) fed with faecal sludge has not been robustly explored despite. Poor management of faecal sludge has adverse public health and environmental impacts and this situation has made majority of the people depend on onsite sanitation as the primary faecal sludge management method (Tayler, 2018).

In response, resource-oriented technologies have been innovated to transform faecal waste such as BSFL, which is reared on fecal sludge and organic waste and can be upcycled into protein- and fat-rich compounds. This has been widely applied in the production of agricultural inputs embodying the insect-based protein for feeding animals (Shelomi, 2020) livestock and poultry and manufacturing organic fertilizer.

Recent studies have demonstrated the potential of BSFL as alternative food and feed sources, either directly or as inputs into livestock production (Chia *et al.,* 2020; Kawasaki *et al.,* 2019). However, there is limited research in developing countries on consumer acceptance of livestock products, such as broiler chicken, raised on BSFL-based feeds. Particularly, application of BSFL reared on fecal sludge may evoke negative emotions or cultural and religious concerns, as products associated with human waste are often considered taboo or unsafe. These socio-cultural dimensions may significantly constrain the reuse of such materials in food systems, despite their sustainability benefits.

Despite growing evidence that black soldier fly larvae BSFL can serve as a sustainable substitute for fishmeal and soybean in poultry diets, most studies have focused on nutritional performance and carcass characteristics, with limited attention to consumer and farmer perceptions. Recent work has demonstrated that BSFL reared on faecal sludge can support acceptable growth outcomes in broiler chickens (Kirimi *et al.,* 2023), yet the use of such waste streams introduces unique challenges related to food safety, hygiene, cultural acceptance, and ethical concerns. While consumer attitudes towards insect-based feeds in general have been studied (van Huis & Oonincx, 2017; Chia *et al.,* 2019), there remains a critical gap in understanding how stakeholders perceive broiler chicken products derived from larvae fed on faecal sludge. Without addressing these perceptual and socio-cultural

barriers, the adoption of BSFL reared on faecal sludge as a circular economy solution for protein production in poultry systems may face significant resistance despite its technical feasibility.

Additionally, a critical gap exists in understanding the sensory characteristics of chicken fed on BSFL-based diets, such as taste, aroma, tenderness, and overall palatability, which are central to consumer decision-making. Sensory evaluation is an important determinant of food acceptance, yet little is known about how Kenyan consumers perceive BSFL-fed chicken from this perspective (Mutisya *et al.,* 2022). Without such evidence, uptake of BSFL-fed poultry products risks being hindered by consumer skepticism, despite the technology's promise in addressing food security, environmental sustainability, and sanitation challenges.

1.3 Objectives

1.3.1 General Objective

To assess consumers and producers' acceptability, attitudes and perceptions of broiler chicken reared on black soldier fly larvae fed with faecal sludge in Kenya

1.3.2 Specific objectives

i. To examine the perceptions and attitudes of potential consumers towards eating broiler chicken whose protein feed has been substituted with BSF in Kenya
ii. To explore the perceptions and attitudes of potential producers in Kenya towards rearing and eating broiler chicken whose protein feed is substituted with BSF.
iii. To compare sensory evaluation tests on broiler chicken whose protein feed is substituted with BSF feed and the conventional chicken.

1.4 Research Questions

i. What are the perceptions and attitudes of potential consumers towards eating broiler chicken where protein feed has been substituted with BSF in Kenya?

ii. What are the perceptions and attitudes of potential broiler chicken producers in Kenya towards the rearing and consumption of broiler chicken, whose protein feed is substituted with BSFL feed?

iii. How do sensory evaluation tests for broiler chicken whose protein feed is substituted with BSFL feed compare with conventional chicken?

1.5 Justification of the Study

Transitioning to a circular economy in sanitation requires not only technological innovation but also societal acceptance. BSFL technology has been identified as a promising pathway in this regard, converting organic waste into high-value protein and fat suitable for animal feed (van Huis & Tomberlin, 2020). In Kenya, research has demonstrated the technical feasibility of using BSFL to substitute fishmeal and soybean in poultry diets (Kirimi *et al.,* 2023; Mutisya *et al.,* 2022). However, such studies have primarily focused on nutritional performance, with little attention paid to the socio-cultural dimensions that influence uptake. Consumer and producer perceptions are critical in determining the acceptability of circular economy innovations, especially when linked to faecal sludge. Literature shows that food-related attitudes, including trust, risk perception, and cultural norms, can significantly influence willingness to adopt or consume products derived from unconventional sources (Verbeke *et al.,* 2015; Parodi *et al.,* 2018). In the case of BSFL-based poultry feed, the potential association with waste—particularly faecal sludge—may trigger skepticism or negative perceptions, regardless of the demonstrated safety and sustainability benefits (Chia

et al., 2019). Without addressing these perceptions, the broader societal transition toward circular food systems risks facing resistance.

This study therefore explores consumer and producer attitudes toward broiler chicken reared on BSFL-based diets. By focusing on perceptions, preferences, and acceptability, the study will generate empirical insights into the social factors that either enable or constrain the adoption of circular economy innovations in Kenya. Such knowledge is vital for designing communication strategies, certification mechanisms, and policy frameworks that not only demonstrate technical safety but also build public trust and acceptance. Ultimately, this will contribute to bridging the gap between technical feasibility and societal acceptance, a crucial step in mainstreaming sanitation resource recovery within circular economy pathways.

1.6 Assumptions of the study

The study assumed that producers and consumers had a basic understanding of conventional broiler chicken production and the type of nutrients and feeds used. The study also assumed that potential producers were culturally open to the idea of using insect-based feeds in poultry production and consumption and were readily available and accessible for use. Additionally, it was assumed individuals' behavior is influenced by their social environment, such as cultural norms, values, and beliefs. The study also assumes that sensory perceptions are influenced by individual differences, and that individuals differ in their sensory perceptions, due to factors such as genetics, age, gender, culture, and experience. Additionally, the researcher assumes that sensory evaluations are reliable and valid measures of sensory perceptions, and that the results can be used to make meaningful inferences and decisions.

1.7 Delimitations of the study

The study specifically focused on consumers within the geographic scope of Meru University of Science and Technology (MUST). The study site being a public university, it was representative of a diverse range of ethnic communities in Kenya. The outcomes of the study could potentially mirror the distinct characteristics of the Kenyan community, thereby potentially ease the broader applicability of the results across the entire country. Additionally, the sensory evaluation tests were concentrated on the attributes of taste, texture, appearance, and odor of the BSFL-fed broiler chicken. By focusing on these selected sensory attributes, the study aims to provide in-depth insights into how consumers perceive these specific characteristics, while acknowledging that other sensory attributes might not be fully explored within the scope of this research.

1.8 Limitations of the study

The sensory evaluation process relies on individual participants' sensory perceptions, which could be subjective and influenced by personal preferences, cultural background, and prior experiences. This subjectivity might introduce variability in the data collected and impact the reliability of the sensory evaluations.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Safely managed sanitation is fundamental for public health and environmental sustainability (Diep *et al.,* 2021). Conversely, efforts to provide access to safe sanitation using sewer systems have recorded less effectiveness for faecal management in low-income countries due to high capital costs, water requirements, maintenance and operation cost, making onsite sanitation systems (OSS) a viable option for faecal waste management. According to Andriessen *et al.,* (2019), 2.8 billion people use OSS methods such as pit latrines and septic tanks to meet their sanitary needs. As a result, over 50% of FS created in low- and middle-income nations is believed to be improperly managed, creating significant environmental and public health problems. For instance, In Dares Salaam, Tanzania, where more than 90% of the population uses OSS, it is estimated that up to 57% of FS is discarded into the environment without being treated. By recovering nutrients and turning part of it into valuable end products, resource recovery and reuse of FS provides an incentive to appropriate faecal sludge management (FSM), hence reducing waste burdens and enticing appropriate FSM (Mkude *et al.,* 2021).

Resource recovery from faecal sludge can take many forms, including fuel, soil amendment, building material, protein, animal fodder, and water for irrigation. These technologies are circular economy based and cost effective (Andriessen *et al.,* 2019). While there has been much research in reuse and recycling faecal waste, few researchers have taken into consideration the social acceptance of broiler chicken reared on BSFL reared with faecal matter in the market.

The world estimates population growth to 9.6 billion by 2050 (Orsi *et al.,* 2019; Jucker *et al.,* 2020) hence, the need to increase the production of food by 70% to be able to sustain the world needs with meat outputs of beef, pork and poultry expected to double (IFIF, 2012). The concerns of food scarcity, economic and environmental sustainability of the current food system are rising and the interest has shifted to more sustainable alternatives to animal feed, protein and pet food. (Ruby and Rozin, 2019; Van Huis *et al.,* 2013). Insects have been reported to contain higher amounts of protein and fat after efficiently converting plant proteins and calories into protein. The paper focuses on insect in the family of S*tratiomydae* such as Black soldier fly larvae (*Hermetia illucens*). Black soldier fly has been reported to feed on variety of organic material and have already been implemented in small-scale waste management using substrates such as manure (Newton *et al.,* 2005), rice staw (Gold *et al.,* 2018), food waste (Hopkins *et al.,* 2021), faecal sludge and kitchen waste (Banks *et al.,* 2014). In the process of waste conversion, BSFL accumulates larval biomass rich in protein and fat which can be used directly as energy. The larvae have recently received the attention for both animal feed (Wang and Shelomi, 2017) and human consumption (Surendra *et al.,* 2016; Sprangers *et al.,* 2016). The larvae have been used successfully as a supplement of fish meal (Belghit *et al.,* 2019) as the larvae contains excellent nutrient composition (Surendra *et al.,* 2016; Chen *et al.,* 2019).

Entomophagy has been practiced in many communities in Southeast Asia, Latin America and Africa. Although entomophagy is practiced in many communities, insects are not consumed by most groups within these areas. Several studies in Western Countries showed that acceptance of insect consumption is lower in these regions due to lack of sensory appeal, unfamiliarity, poor image, disgust and low availability (Ruby *et al.,* 2015). Recent research

has shown that incorporation of insects into familiar foods can increase appeal (Gmuer *et al.,* 2016), but there are other ways to increase acceptance. However, there is little research on acceptance of insects by the consumers and producers in Sub-Saharan cultural context.

2.1.1. Insect as animal feed

The world market value for insects has rapidly increased from 20% to 30% per annum with the trends of innovating new alternatives for conventional ingredients (Kim and Hong, 2022). Asia-pacific countries are the biggest market for edible insects, however, there is no legislation. Insects' meals are made available through freezing, heating, grinding, extraction and hydrolyzation procedures (IPIFF, 2019). The insects are cleaned and dried through freezing, chilling and drying to help prevent microbial growth during long term storage and transport. The insects are dried to 5% moisture content to limit microbial degradation and nutrient degradation (Kröncke *et al.,* 2019). The dried insects are finely grinded into small particle size or subjected to hydrolysis or oil extraction. Recently, research on Swine on use of BSF larvae on suckling pigs has been done in African countries (Chia *et al.,* 2019).

Among edible insects, yellow mealworm, black soldier fly and common housefly have been considered as an alternative protein source for pigs (Spranghers *et al.,* 2018). These insects are easy to grow and breed in organic wastes and they contain a well-balanced nutritional value as a source of protein. The black soldier fly larvae could replace the fish meal in the diets without adverse effects on growth performance and nutrient digestibility. Furthermore, Black soldier fly has also been included in pigs' diet with no negative effects on growth and quality of the market pigs (Ao *et al.,* 2020). The BSF has been having been allowed as an ingredient as feed for aquaculture in the United States and has also been authorized for poultry use in Canada (Tan *et al.,* 2020). The European Union has legislation that authorizes

the use of processed insect meals and animal protein in feeds for pigs and poultry. Various insect species including BSF or mealworm has been carried out in China for weaned pigs (Ji *et al*,.2016), in South Korea (Jin *et al.,* 2016; Ao *et al.,* 2020), in Europe (Spranghers *et al.,* 2018; Chia *et al.,* 2021). Previous studies reported that dried BSFL larvae contain 42% crude protein and 42.5% of ether content (Spranghers *et al.,* 2018). However, consumers have a negative perception on edible insects which are consumed directly compared to indirect consumption of insects (Kim and Hong, 2022).

BSFL meal is a suitable ingredient in poultry and pig diets because of good palatability and its high content of amino acids and calcium (Makkar *et al.,* 2014). The insect contains high fat and ash content and that is why the larval meal can be mixed with other proteinaceous ingredients. A study by Newton *et al.,* (2005) reported that digestibility of nitrogen and dry matter tended to be easier for soybean compared to BSF meal because of the additional cuticles on BSF that needed refinement. BSF prepupae and larvae has been used as feed additive for young chicks. The partial replacement of 20% of soymeal showed a great production performance, carcass traits and feed efficiency similar to those fed on commercial diets (Cullere *et al.,* 2016). Maurer *et al.,* (2016) study replaced 50% of the soybean cake with defatted BSFL meal and recorded no effect on egg laying performance and feed efficiency.

In addition, the replacement of protein in fish diets using BSFL meal has been reported in the following species: channel catfish (Zhang *et al.,*2014), hybrid tilapia (Furrer. 2011), rainbow trout (Sealey *et al.,* 2011) and Atlantic salmon (Lock *et al.,* 2015). The cited studies showed that low inclusion of BSFL levels recorded similar performance with traditional feedstuffs due to its high protein content (Zhang *et al.,* 2014). Higher inclusion of

BSFL larvae in fish meal could affect the palatability of protein digestibility. For example, a study by St-Hilaire *et al.,* (2007) showed that the replacement of fish meal with insect meal increased the amount of fat or lipids in fish that led to change in taste /flavor of fish fillets. The complete replacement of commercial feeds with BSF larvae during rearing of alligators resulted in lower growth and consumption.

While technical studies demonstrate the nutritional suitability of BSFL in animal feed, consumer and producer perceptions remain a major determinant of adoption within circular food systems. Research has consistently shown that attitudes toward insect-based products are shaped by cultural values, health concerns, and sensory expectations. For instance, Higa *et al*. (2021) found that American consumers were more willing to consume BSF-based products when insects were processed into flour or oil, rather than in visible form, suggesting that disgust and perceived benefits strongly predict acceptance. Similarly, Tan *et al*. (2015) reported that socio-cultural associations in Thailand, such as linking insects with decay, contributed to rejection of insect-based foods.

Perceptions also extend to indirect consumption of insect-fed products. In Kenya, Khaemba *et al*. (2022) found that consumer attitudes toward eggs from chickens reared on BSFL meal were mixed, with negative perceptions driven by awareness of the feed source and positive perceptions linked to understanding the nutritional benefits. In European markets, studies highlight that health concerns, food neophobia, and cultural norms remain barriers to acceptance of poultry and fish reared on insect-based diets (Biasato *et al.,* 2019; Domingues *et al.,* 2020; Szendro *et al.,* 2020). Cross-cultural research in China and Germany further revealed that neophobia, social acceptance, and taste expectations strongly predicted willingness to consume insect-fed products (Hartmann *et al.,* 2015).

These findings suggest that, while BSFL meal is nutritionally comparable to conventional feed ingredients, its broader adoption depends on addressing consumer and producer perceptions. In developing countries such as Kenya, where sanitation-linked stigma may influence acceptance, little is known about attitudes toward broiler chicken reared on BSFL diets. This highlights a critical gap in literature, necessitating empirical studies to understand how perceptions and acceptance shape the integration of insect-based feeds within circular economy pathways.

2.1.2 Black soldier fly life cycle

The Stratiomyidae family member known as the black soldier fly (*Hermetia illucens*) has a significant potential for recycling bio-waste streams (Mertenat *et al.,* 2019). Black soldier fly lifetime is predicted to take 37–40 days under good raising conditions, but it can take up to 2 months in insufficient rearing situations (Salam *et al.,* 2022). According to Li *et al.,* (2011), the black soldier fly has four life stages: egg, larva, pupa, and adult, with the juvenile and pubertal stages taking up the most time. These stages are the most time-consuming but crucial ones in waste management because this is where the majority of garbage is consumed and converted. Absence of a mouthpart, stinger, and digestive organs prevents adult BSF from biting or ingesting food (Lalander *et al.,* 2019). Adult BSFs range in size from 15 to 20 mm, with males having a bronze abdomen and females having a reddish-brownish colour (Mertenat *et al.,* 2019). The adult male and female flies oviposit only once during their lifetimes, and the male fly emerges before the female.

The life cycle begins with adult mating, which results in 500–900 eggs being laid singly in moist organic material near dry cervices during breeding (Liu *et al.,* 2017). Eggs become larvae within 3–4 days of being laid (Hoc *et al.,* 2019). The newly formed larvae enter the

food and consume it, breaking it down. An unusual microbiota structure in the insect's gut enables it to break down a variety of organic waste. According to Makkar *et al.,* (2014), the larvae can reach a maximum size of 27 mm in length, 6 mm in breadth, and 220 g in weight. The larvae develop into prepupa in about two weeks if the right conditions are present, including food, the right temperature, and humidity. The prepupa emerges from waste after passing through all six instars by finding a dry area to burrow in (Wang & Shelomi, 2017). Because of its migratory habit, the insect is easily captured for use as food for animals or to develop into a pupa (Cickova *et al.,* 2015). Fat is then transformed into energy to support adult life and reproduction after this point (Sheppard *et al.,* 2002). Additionally, there are environmental factors that are essential for BSF growth, including temperature, humidity, and light (Salam *et al.,* 2022).

Pupation is marked by the growth of a casing (puparium), the body becoming stiff, and immobility (Salam *et al.,* 2022). Prepupa turn into pupa in roughly 7–10 days. For 8 days, the pupa is in its sleeping period, which allows the embryo to continue developing into its exoskeletal sheath (Banks *et al.,* 2014). When the casing is fully formed, it pulls away at the tip and releases an adult fly, a process known as emergence (Salam *et al.,* 2022). Newly emerging adult flies have folded and immature wings that gradually develop over the period of two to three hours, in contrast to the wings of one-day-old adults. They also have bodies that are a little bit larger, softer, and greenish in hue (Gao *et al.,* 2019). The brief lifetime provides a sustainable source of larval production and is essential for frequent reproduction.

2.1.3 Nutrient composition of Black soldier fly

The nutrient composition of BSFL varies depending on the type of substrate used. On average, BSFL contain high protein and fata content and the body composition is dependent

on quantity and quality of ingested food (Zheng *et al.,* 2012; St-Hillaire *et al.,* 2007; Nyuyen *et al.,* 2015). BSF larvae contain protein content of 45% from BSF feed on various organic waste (Kinasih *et al.,* 2018), 33% of protein content from kitchen waste (Danieli *et al.,* 2019), 45.4%, 43% and 36% of larval crude protein from faecal sludge, brewers and food waste ((Nyakeri *et al.,* 2017), 44.6%, 37% of protein content from different substrates ((Dortmans *et al.,* 2017).

Black soldier flies are a great source of crude fat for animal and poultry feeds. For instance, (Mutafela, 2015) recorded a fat content of 41.7% from BSF grown on fresh fruit waste, Yue *et al.,* (2019) reported a range of 31%-35% of larval fat content from animal manure. Moreover, (Newton & Burtle, 2005)) reported a fat content of 28% from swine manure, 33.60%, 38.60% and 37.10% of fat content on chicken, restaurant waste and vegetable waste on dry weight respectively (Sprangers *et al.,* 2017). It is noted that the presence of much fat in substrates is detrimental to larval production because the larvae face difficulties in breaking down the fat during the process of metamorphosis into adult (Nguyen *et al.,* 2015).

The variations in BSFL nutrient composition exists throughout the larval development process. For instance, crude protein content decreases with age, its higher in younger larvae compared to old larvae (Rachmawati *et al.,* 2010). In addition, depending on diet and larval stage (Rachmawati *et al.,* 2010), fresh larvae have a dry matter concentration of between 20 and 44% (Diener *et al.,* 2009; Nguyen *et al.,* 2015. Dry matter is higher in the later instars.

The amino acid composition of dried BSF larvae appears to vary somewhat depending on the diet of the larvae (St-Hilaire *et al.,* 2007), whereas the amino acid composition of larvae fed either swine manure or cattle manure (Newton *et al.,* 2005) tends to be slightly lower. According to the amino acid profile, BSF larval protein is notably high in lysine (6–8% of

protein content) and corresponds favorably to levels previously reported for animal feed (Sheppard *et al.,* 2008). Lysine, leucine, phenylalanine, and threonine levels in larvae grown on swine manure, for instance, are comparable to soybean meal levels (Newton *et al.,* 2005). Based on 16 g N values, BSF larvae had larger concentrations of the amino acids such as alanine, histidine, methionine and tryptophan than soybean meal, but lower concentrations of the amino acid arginine.

The total fat content of BSF larvae and prepupae has been reported to contain 58–72% saturated fatty acids and 19–40% mono- and polyunsaturated fats, with significant levels of palmitic, lauric and oleic acid (Surendra *et al.,* 2016). It appears that the nutritional fatty acid (FA) content affects the lipid profile of larval and prepupae. For instance, when these are present in their diet, BSF prepupae may ingest -linolenic acid and (Sealey *et al.,* 2011; St-Hilaire *et al.,* 2007a). According to Oonincx *et al.,* (2015), there are few opportunities to modify the FA profile of BSF larvae since higher dietary fat content causes a greater proportion of FA to be converted to lauric acid.

In comparison to other insects utilized in managed feeding programs, BSF larvae have higher mineral concentrations (Dierenfeld and King, 2009). High amounts of phosphorus (P), mineral calcium (Ca), iron, zinc (Zn), copper (Cu), phosphoric (P), and manganese (Mn) are also present, with the greatest Ca: P ratio being 8.4 (Makkar *et al.,* 2014). When compared to other insects, sodium (Na) is present in lesser concentrations (Dierenfeld and King, 2009). The mineral contents of BSF larvae raised on either pig or poultry manure varied, according to Newton *et al.,* (2005), presumably due to variations in mineral availability or concentrations in the two types of manure. For instance, BSF raised on chicken manure had considerably greater P content. Ash content is substantial and ranges from 9 to 28% DM

(Makkar *et al.,* 2014). The fact that the epidermis of BSF secretes a coating of calcium carbonate (CaCO3), which may account for the high Ca and ash content may help to partially explain the high Ca content in BSF larvae.

2.1.4 Challenges of using Insects as food

Research has shown how important it is for consumers to be concerned about products made using feed derived from insects (Joel, 2018; Onsongo *et al.,* 2017; Rumpold & Schlüter, 2013). This is a result of the way that the use of insects in chicken production is now being considered. Since consumers are products' final users, it is expected that they will have preferences, which affects how well a freshly designed product performs. Customers are most concerned about the new product's potential to satisfy their nutritional needs without endangering their health (Onsongo *et al.,* 2017). Diverse consumer issues stem from variations in their individual attributes (Lancaster, 1966).

There are a number of difficulties associated with using black soldier fly larvae as a sustainable supply of protein, though. There are no precise regulations on the use of insects as food since there is a lack of clear legislation, murky rules, and omissions in policy documents like those published by the Kenya Bureau of Standards (KEBS). The commercialization of insect farming has been dragged down by an inadequate regulatory framework (Halloran *et al.,* 2015). Although KEBS has established policies and procedures for the use of black soldier flies as animal feed, there is still a need to provide participants in the value chain with sufficient knowledge (KEBS, 2017). Insects are considered pollutants in food and feed, as per the Sanitary and Phytosanitary Standards (SPS) of KEBS (Halloran *et al.,* 2015). Regulations are necessary to protect the production of insect-based feed, according to earlier research on consumer approval of using insects (Dörper *et al.,* 2021;

Sogari *et al.,* 2019). This suggests that the underlying design is impacted by and plays a critical role in the development of consumer attitudes in policy.

Indigenous chickens eat insects in their informal meals. Depending on the substrate used to raise black soldier fly larvae, concerns have been expressed regarding the presence of dangerous elements such as heavy metals, toxins produced by or collected by the insect, pesticide residue, and veterinary medicine residue (Van der Camenzuli *et al.,* 2018). Due to the fact that these insects eat garbage, entomophagy and the usage of insects as food have become socially stigmatized. Allergens related to insects can also be problematic when raising them (Rumpold & Schlüter, 2013). Due to the processing methods employed, not many processors are able to have adequate storage to hold for a longer capacity, raising concerns about the insects' shelf life (Rumpold & Schlüter, 2013).

2.1.5 Black Soldier Flies in Waste Management

Africa faces the problem of waste management because it is a continent with middle- and low-income countries. It generates a lot of solid waste, of which organic material makes up 56% (UNEP, 2018). The issue is made worse by rapid urbanization and population increase, shoddy planning, and inefficient waste management systems (Wilson, 2015). Methane, a dangerous greenhouse gas that contributes to global warming, is released more frequently when garbage is dumped in an unregulated manner (UNEP, 2018). This has led to a change in the search for waste management substitutes. A potential waste management solution that produces byproducts that may be utilized as fertilizer and transforms biowaste into protein for animal feed is black soldier fly larvae (Miranda *et al.,* 2019).

According to Li *et al.,* (2011), black soldier fly larvae are capable of converting and sterilizing biodegradable waste, such as farm manure and leftover vegetable and animal food.

Organic waste would leak greenhouse gases into the atmosphere and worsen global warming if left in the environment. Larvae of the black soldier fly had a 50% reduction in waste. According to Makkar *et al.,* (2014), they quickly convert garbage, which lessens the smell from decomposing waste. The population of the common housefly (Musca domestica), a disease vector, can be managed with the use of black soldier fly larvae, enhancing both human and animal health. The generation of biodiesel from black soldier fly larvae is now being investigated as a viable source of renewable energy. But the primary obstacle is its production expense since it requires feedstock (faecal waste, kitchen waste, vegetables).

The role of BSF in sustainable waste management has been widely documented, with research highlighting both environmental and economic benefits. Diener *et al*., (2011) demonstrated that BSF larvae can reduce organic waste volumes by up to 70% while simultaneously producing nutrient-rich residue suitable for agricultural application. This dual capacity to minimize waste and generate valuable byproducts underscores the potential of BSF technology to support circular economy initiatives, especially in regions struggling with inefficient waste management systems.

Beyond volume reduction, BSF treatment has also been shown to improve hygienisation of organic waste. Lalander *et al*., (2019) reported that BSF larvae substantially decreased pathogen loads in waste substrates, making the process safer compared to conventional composting methods. This ability to manage waste while suppressing harmful micro organisms positions BSF as a bio-secure and sustainable strategy for resource recovery. Collectively, such findings affirm the contribution of BSF technology in reducing environmental pollution, mitigating greenhouse gas emissions, and advancing waste-to-value pathways in low- and middle-income contexts.

2.2 Consumers perception and attitudes on eating broiler chicken fed on BSFL meal

The perception of people towards the consumption of eggs from layers fed with BSFL-integrated meal needs to be given attention. A study by Khaemba *et al.,* (2022) on evaluating the perception of consumers towards eggs from BSFL diet fed hens and the socioeconomic factors that influenced perceptions. The study used 200 consumers from Kiambu County and the results revealed that 65% of the participants were aware of the benefits of using proteins from insects for poultry feed. Preferences and willingness to consume eggs from the hens was shown by 70% of the respondents. The key aspect that influenced consumer willingness to consume eggs were ethics, the perceived benefits and traceability. Among the other socioeconomic factors were household size, awareness of insect feeds, off-farm income, access to credit and gender influenced the perceptions of consumers. The study concluded that creation of awareness and evidence-based demonstrations on the benefits of BSFL incorporation in poultry feed would improve the consumer perception and upscale uptake of the BSFL treatment technology.

Perception of insect-based feeds commercially by farmers have been reported in recent studies (Chia *et al.,* 2020; Okello *et al.,* 2021). A study by Ferrer Llagostera *et al.,* (2019) on willingness to pay for insect fed fish products in Spain revealed that 60% consumers were willing to pay premium for the insect-fed fish products. The study indicated that understanding of the key drivers that can hinder consumers perception such as price, environmental and animal welfare would be necessary on way forward to the new technologies (Spartano and Grasso, 2021). Previous study by Mawia (2018) on attempt to understand the willingness and preferences to pay for poultry meat from chicken fed on insect-based diet showed 93% and 59% acceptability and consumer willingness to pay for

the meat consecutively. The study recommended that there is urgent need for awareness creation to improve consumers preferences.

The willingness and acceptance of products derived from insect fed chicken and fish has been reported in European markets (Biasato *et al.,* 2019; Domingues *et al.,* 2020; Szendro *et al.,* 2020). However, the perception regarding health aspects and nutrition of the eggs were more ranked as the main reason that hindered acceptance. Similarly, the health and nutrition status of insect-based foods are among the major concerns among consumers (Onyango *et al.,* 2006). Nichani (2005) reported that labelling the eggs of insects could be an important consideration to limit unwillingness. However, the notion of labelling was challenged by Balcombe *et al.,* (2016) study which reported that labelling was not sufficient to inform consumers on the insect derived product acceptance. The study identified alternative marketing policies and ways to provide consumers with necessary information through media.

There are various studies that have focused on willingness of people to substitute the meat with insects (Verbeke, 2015; Vanhonacker *et al.,* 2013; Schosler *et al.,* 2012). A study in Belgian reported that more than 65% of the participants disagreed with the concepts of insect substitution with insects (Verbeke, 2015). In Netherlands, meat substitution attractiveness ratings and likelihood to prepare meals like locust or mealworms was lower (Schosler *et al.,* 2012). Among the Flemish consumers, the insect protein received the lowest interest compared to other foods in terms of what they were willing to purchase and pay for (Vanhonacker *et al.,* 2013). Additionally, a study by Hartmann *et al.,* (2015) on the cultural comparison of eating insects using 443 and 502 adults from China and Germany. The study focused on the willingness to consume different insect-based foods (processed, baked or

unprocessed) mainly the neophobia on consumers' willingness. The Chinese regarded all insect-based food as favorable with regards to nutritional value, taste and social acceptance compared to Germans. German was more willing to eat processed insect-based meals than unprocessed foods (Hartmann *et al.,*2015). The issue of neophobia, social acceptance and taste expectations were among the higher predators of consumer willingness to consume insects in both countries.

The consumer acceptance of consuming insect-based products is determined by beliefs and product perceived attributes which are the main factors considered in food decision making and preference process. Cultural influences, beliefs and attitudes and social appeal have been reported to have a great impact on consumption of insect-based diets. A study by Rozin and Fallon (1980) reported that culture, previous experience and social norms shape the boundaries of what is perceived as inedible and edible. The visual appearance of the BSFL food triggers disgust-based food rejection. A study by Martins and Pliner (2006) reported that perceived mouth feeling and texture properties of the food led to food being rejected based on disgust.

Effects of culture on the perception of eggs from BSFL fed chickens is among the factors that hinder preference and acceptance (Tan *et al.,* 2015). The cultural effect on people's capability to consume insects is tied to psychological factors, sensory evaluation and socio-cultural factors (Verneau *et al.,* 2016). An exception is reported by Tan *et al.,* (2015) which traces the socio-cultural factors affecting the acceptance of insect foods. For instance, mealworms were rejected as food in Thailand due to its association of decaying matter. A study by House *et al.,* (2016) in Netherlands on consumer acceptance of insect-based foods reported that the leading factors associated with consumption were taste, price, dietary

practices and product availability. Shelomi (2015) also reported that negative factors such as the expensiveness of insect foods lead to passive rejection of the foods. The study focused on consumers in Netherlands on insect-based foods. The participants were motivated to try insect foods due to taste, availability and price (Thrastardottir *et al.,* 2021).

Previous experiences with insect-based foods have an impact on individual attitudes about willingness to consume the food. Underlying psychological factors connect the attitudes to consumer behavior towards the products. Some communities find insects unfamiliar and this provokes rejection and avoidance of insect-based foods. The decreased level of willingness to eat new foods is associated with food neophobia (Verbeke, 2015), taste expectation (Fallon and Roxin, 1983) and uncertainty on the product origin (Tuorila *et al.,* 1994). Reducing the uncertainty of the food could be solved by giving information about having them mixed with familiar products to promote uptake. For instance, a study done on Belgian visitors on willingness to consume insects showed that insects with known flavors (Chocolate or paprika) were more preferred to boiled and baked crickets and mealworms (Caparros *et al.,* 2014). The study concluded that adding flavors and spices to insect-based foods helped to decrease the neophobic reaction and increased the willingness to taste new food.

Use of human urine in agriculture has been associated with being subjected to social stigma. On the contrary cow urine is deemed acceptable and having nutrients that support plant growth (Sutradhar *et al.,* 2021). Use of BSF as an alternative protein source has been embraced commercially to feed animals (Kawasaki *et al.,* 2019). However, it presents a challenge to the status of food produced due to the nature of the feed formulation that contains faeces; this raises concern to many, but particularly may be a concern for the

Muslim community because of religious beliefs (Jamaludin *et al.,* 2021). This indicates a number of causes influencing the rate of consuming products associated with human excreta.

2.3 Producers perception and attitudes on rearing and eating broiler chicken fed on BSFL meal

BSFL has been acceptable as other insects such as Mealworm, ants and crickets. It has been relatively well perceived and promising alternative to animals as pet food. A study by Higa *et al.,* (2021) on attitudes of Americans adults towards incorporation of BSF larvae as whole dried insect or insect flour into familiar foods. The study assessed the willingness of the people to eat BSFL directly, eat animals fed on them, and use BSFL as dog pet food. The results showed that participants were more willing to try eating food from insect flour or rendered fat than having the whole insect, similarly to acceptability of using insects as dog food. Consequently, the participants had negative attitudes about eating BSFL directly. The study concluded that it was easier to use indirect ways of insect consumption like consuming animals fed on insects are more acceptable compared to direct consumption.

Information about the acceptance of BSF derived products due to little information. A study by Kragt *et al.,* (2023) on the acceptance on the use of BSF derived fertilizer among Australian farmers reported that farmers agreed on the use of BSF fertilizer in granulated form as it improved the environmental sustainability. The farmers willingness to pay was more in producers who were regenerative compared to conventional farmers. The acceptance level of insects as human food is low (Verbeke, 2015), other than a certain study reporting that 64% of the American participants were willing to consume insect-based food (Ruby *et al.,* 2015). The difference in the findings could be attributed to age (Verbeke, 2015), or the country of study (Payne *et al.,* 2016).

A study by Bulinda *et al.,* (2023) on farmers awareness on the potential of insect farming as an ingredient in livestock feed. The study used 235 poultry and pig farmers in Kiambu County, Kenya and the results indicated that 44% of the farmers were aware of using black soldier fly in feed industry however, the results were affected by age and education. Furthermore, Ouko *et al.,* (2023) study evaluated the factors that influenced fish farmers awareness on use of black soldier fly as an ingredient in fish meal. The farmers' experience, farmers income and knowledge influence the farmers awareness on BSFL meal. The farmers communication and education helped in improving the farmers awareness on new fish feed ingredients. The study suggested that both private and public institutions need to improve the awareness creation through electronic media and local print to upscale fish farmers to insect-based aquafeeds.

Large-scale adoption of farmers acceptance on perception of the commercial insect-based food. The study applied 320 farmers and the study reported that over 90% of the farmers were willing to use insect-based foods due to its performance, feed versatility, social acceptability and purchase decisions. The farmer's perception was highly influenced by off-farm income, education, wealth status, group membership and awareness. The study concluded that experimental demonstrations were beneficial for farmers technical knowledge on the insect-based feeds productivity of livestock and reduce uncertainties (Okello *et al.,* 2021).

Major challenges to poor attitudes among farmers towards livestock production in developing countries using insect-based meals have been tied to limited access to good quality and adequacy or affordability. A study by Odinya *et al.,* (2022) on farmers intention on use of insect-based feed in feeding the dairy cattle diets in Murang'a county, Kenya. The

study used theory of planned behavior on 378 dairy farmers and the findings showed 11% of farmers were aware of the use of insects as source of protein in livestock production. About 76% were willing to apply insects as an alternative source when made available. The farmers' decision was influenced by attitudes, perceived behavioral control and subjective norms. The age of farmers, farming experience, access to extension services, wealth status and flock size were positively associated with farmers intention on use of insect-based foods. The perception and willingness of the poultry farmers to use insects as an alternative source of proteins in poultry feed. A cross-sectional study was carried out on 287 poultry farmers, 71 feed traders from three culturally diverse regions in Uganda. The study revealed that 70% of the farmers expressed willingness and most of them mixed their own poultry feed. However, some farmers had doubts about the possibility of acquiring insects in large quantities. The study concluded that there is a higher potential of insects in poultry feeds if they can be generated in sustainable quantities and viability (Sebatta *et al.,* 2018). Farmers awareness of the use of insects and its frequency of price influenced the farmers acceptability. Farmers kept the poultry in free range systems where birds scavenged for insects without farmers efforts hence farmers didn't feel the need to rare insects. On the other hand, respondents rearing exotic chickens commercially are not easily convinced to take up new ideas of feed (Marra *et al.,* 2003). The farmers belief that insects are good and being of age would influence the willingness to use insects in poultry feeds. (Sebatta *et al.,* 2018).

The cost of providing quality protein in chicken diets was a hamper to chicken production in South Africa (Gunya *et al.,* 2019). The study evaluated the attitudes of chicken farmers in villages of South Africa on use of earthworms as source of protein for chicken using 150

questionnaires. The study revealed that rearing of earthworms were more favored by male farmers while youth farmers rejected it. The farmers willingness to consume chicken fed on earth worms was greatly influenced by chicken ownership. However, the farmers' perception on the health risks associated with rearing of earthworms affected the uptake (Gunya *et al.,* 2019). Weinreis *et al.,* (2023) on 517 Germany farmers on their willingness to use insects in livestock farming. The study findings showed that the farmers' willingness to adopt insects depended on the psychological, personal and farm structural variables while age, neuroticism and use of available resources were the major limitation of the use of insect-based foods.

The perception of fish farmers on use of insects in fish farming is important for the acceptance of using insects as alternative protein source (Ssepuuya *et al.,* 2019). A cross-sectional study using 208 fish farmers and 71 fish traders in Uganda. The study had equal participants for both youths and adults and 94.9% of the farmers and 91.5% of the traders were willing to use insect feeds but only 44.8% and 8.6% of fish farmers and fish traders had ever used insects in their meals. The willingness to use insects such as termites, grasshoppers and cockroaches was positively correlated with farmers perception and familiarity that insects was a good source for nourishment for fish meals (Ssepuuya *et al.,* 2019). A study by Okello *et al.,* (2023) on the willingness of farmers to pay for insect-based chicken feeds in Sub-Saharan Africa. Using 314 chicken farmers in Kenya, the study showed that farmers were willing to pay premium prices from US 0.35 TO US 3.35 for insect-based feed ether in form of pellets or mash. Waithanji *et al.,* (2020) study on attitudes and practices among poultry and pond fish farmers from Kisii, Kirinyaga and Nakuru in

Kenya revealed that women were more involved in poultry and men into fish farming. The insect fed chickens were bigger and tastier.

Negative attitudes toward the use of insect-based foods and the explanation given by the Europeans farmers were food neophobia which is the unwillingness to try novel foods (Faccio & Guiotto, 2019; Petrescu-Mag *et al.,* 2022). Consumers neophobia has been reported to reduce the willingness to eat insects' either as whole or as an ingredient in food (Siddiqui *et al.,* 2022). However, neophobia is a complex attitude and can change in one's life over time and this makes it not a significant barrier to insect consumption (Faccio & Guiotto, 2019). A study by Thrastardottir *et al.,* (2021) reported that the attitudes towards edible insects was influenced by idioms with unfavorable references affected by anger, disgust and attitude.

Disgust is another issue that has been reported to cause unwillingness in insect consumption. The Europeans consider insects dirty (Petrescu-Mag *et al.,* 2022) and as a pathogenic risk (Castro & Chambers, 2019). The feeling of disgust affects the perception of farmers willingness to consume foods. Disgust can be wired towards the culturally induced rejection (Sogari *et al.,* 2022). It is therefore conceptualized that information can change that over time. People can change their food preference through exchange, information and experience (Sogari *et al.,* 2022).

Several studies have been conducted to assess the efficacy of the byproducts of human faecal sludge ranging from agricultural inputs to animal feeds. Moya *et al.,* (2019), conducted a study to examine the efficacy of the fertilizer derived from human faecal sludge in agriculture and the farmers' perception of its consumption. Manufacturing of the fertilizer from human FS essentially addressed the underpinned challenges. The study analyzed the

fertilizer quality produced from human FS and assessed consumer perception in the local market using an experimental design in assessing three different fertilizers derived from human FS against inorganic fertilizer. The results revealed that the fertilizers derived from human excreta had comparable yields to the chemical fertilizers (Moya *et al.,* 2019). Additionally, results revealed that many farmers in Haiti and Kenya perceived fertilizers derived from human FS as acceptable (Moya *et al.,* 2019).

A study in Tanzania was conducted to assess the knowledge, attitude, and practices on reusing resources recovered from faecal sludge using a household survey anchored on the framework's three key components: knowledge, attitude, and practices (Mkude *et al.,* 2021). The study results demonstrated that the residents had little knowledge of faecal sludge, resource recovery, and reuse. The residents had a negative attitude towards using the faecal sludge-derived products, except for products that were not directly consumed, such as the biogas and the FS-briquette.

Market feasibility of the sanitation derived products including faecal sludge, municipal solid waste-based composition influenced the farmer's willingness to pay for the attributes of the products. The study examined three key attributes; fortification, palletization, and certification (Danso *et al.,* 2017) and revealed that farmers were willing to pay $ 0.4 above per kilogram of FSM compost and placed a higher worth on compost-certified products. Summarily, the study revealed an excellent potential for recycled products and supported the circular economy; however, a good market was required to effectively sustain the operations in FSM (Danso *et al.,* 2017).

2.4 Sensory Evaluation on broilers chicken fed on protein feed substituted with BSF feed

Studies have focused on the partial replacement of fishmeal and soybean meal by insects on poultry performance. However, the sector is still in its infancy as several uncertainties remain unaddressed (Dorper *et al.,* 2021). BSFL are suitable sources of protein for poultry. However, the effect of live Black soldier fly supplementation on chicken broilers performance and behaviors has not been quantified. Insects have rapidly emerged as an innovative feed in improving the sustainability of meat production (Cullere *et al.,* 2018). However, there is limited knowledge about the sensory traits of the derived sanitation products. Therefore, the need to test the effect of partial substitution of black soldier fly larvae to replace soya bean meal during growing of broilers. A study by Cullere *et al.,* (2018) on substitution of soya bean meal and oil with black soldier fly for growth of broiler quails. The study studied the effect of the substituted meal on meat production, amino acid, minerals and sensory characteristics in three dietary treatments. Quails of 10-28 days of age were fed with control diet, 10% and 15% diet inclusions which were slaughtered and breast meat used for evaluation. The sensory status, oxidative status and cholesterol content were not affected by the supplementation but with the increase in black soldier fly larvae inclusion, the saturated fatty acids, however, these lowered the healthiness of the breast meat. The study suggested further research on the extent to which fatty acids profile can be improved.

The texture and flavor of BSFL has not gotten any attention they deserve in entomophagy texts. The assumption that insects will be accepted as meal substitutes when society deals with the taboos of eating insects leads to ignorance of how the insects' tests or feel. A study

by Ruby, Rozin and Chan (2015) focused on psychographic profiles of consumers willing to adopt insects. The study showed that men with high sensation seeking, low in disgust sensitivity, food neophobia and willing to talk about their unusual experiences in eating were likely to consume insects. Similarly, Younger males with week attachment to meat, willing to test new foods and have interest in environmental impact of food choices are likely to consume insects. Therefore, identifying the characteristics of consumers provides important information for sustainable protein industry to accurately target, segment and marketing to consumers (Verbeke, 2015).

Modification of protein sources and levels in poultry meals have been reported to affect the gut histomorphology of broilers and influence absorption and nutrient digestion (Dabbou *et al.,* 2018). In the study of Cutrignelli *et al.,* (2018) on the intestinal morphology of laying hens fed on defatted black soldier fly meal showed differences between the animals fed with insects compared to those feed on standard diet. The hens fed on BSFL showed higher villi height in the duodenum. Similarly, Dabbou *et al.,* (2018) study used 256 male broilers chicken from day one to thirty-five using four dietary treatments (HI0, HI5, HI10 and HI5) in starters, grower and finisher. Two birds were slaughtered per treatment and the results showed that increasing levels of dietary BSFL meal in male broilers chicken improved the weight and daily feed intake as well as affect negatively the gut morphology and feed conversion ratio.

BSFL have been investigated for their effect as larval meal in broiler chicken growth performance (Dabbou *et al.,* 2018; Boreva *et al.,* 2016; Biasato *et al.,* 2019). Several studies have been carried out on laying hens (Star *et al.,* 2020) and turkeys (Veldkamp and Van Niekerk, 2019), broiler chicken (Ipema *et al.,* 2020). A study by Oddon *et al.,* (2021) on the

inclusion of BSFL using 180 four-day old male broiler chicken which were slaughtered at 39 days, showed that the substitution did not affect the bird performance and health status. A study by Veldkamp and Van (2019) on use of BSFL as feed for turkey poults. A study used 20 turkeys per pen for 35 days and provision of BSFL reduced aggressive pecking in turkey and the incidence of skin and feather damage were low in BSFL fed turkey.

A study by Biasato *et al.,* (2018) evaluated the animal performance, intestinal morphology and haematochemical features of the broilers chicken fed with Tenebrio molitor (TM) larvae meal using 160 female chicks of 1 day old in four treatments (TM 50, TM100, TM150 and the control). At age of 40 days, two birds per treatment were slaughtered and traits were recorded. The intestinal morphology showed a liner response showing that increasing the dietary TM meal inclusion increases the chicken weight and feed intake as well as worsen the feed efficiency. Similarly, a study by Bovera *et al.,* (2016) on the effect of Tenebrio Molitor Larvae (TML) as a replacement of soybean meal on nutrient digestibility, meat traits and growth performance using 80 birds 30- day old male brown broilers. At age of 62 days, two birds per group was slaughtered and TML fed broilers reported improved feed conversion ratio and showed higher digestibility. The length of the intestines was greater in TML fed broilers compared to soybean meal fed broilers.

Sensory properties of the insect fed meat affect the acceptance and willingness to use BSFL incorporated meals. A certain survey-based study identified poor sensory experience as one of the factors causing rejection of insect foods (Ruby *et al.,* 2015; Hartmann *et al.,* 2015). However, there is a great acceptance when insects are incorporated as processed meals compared to whole (Hartmann *et al.,* 2015; Gmuer *et al.,* 2016). Similarly, studies that have engaged participants in consumption of food incorporated with insects reported higher

acceptance when insects were concealed or presented in familiar forms (Lensyelt *et al.,* 2014; Sogari, 2015; Tan *et al.,* 2015) or flavors (Tan *et al.,* 2015). Insect inclusion in feeds as a cheaper protein source has been implemented where BSFL meal has been partially replaced with fish meal and soy meal in broilers chicken to determine the effect on carcass characteristics, sensory attributes and growth performance in 0, 5. 10. And 15% diets. The diets were fed to 288 broilers chicks and the study demonstrated that the replacement rate had no adverse effect on feed conversion rate and taste of breast meat.

Taste is also important in determining whether BSFL- based foods are accepted or not (Hartmann *et al.,* 2015; Schouteten *et al.,* 2016). The study by Schouteten *et al.,* (2016) examined the liking, quality and nutritiousness, emotional sensory of burgers under blind, informed and expected conditions using 97 young participants. The study revealed 10% of the participants were unwilling to consume insect-based burgers under informed conditions but tasted the same burger under blind conditions. Complete assimilation of the insect-based burger was influenced by liking. The informed condition had little influence on emotional sensory. However, a study by Tan *et al.,* (2016) explored on how sensory liking and food appropriateness affects willingness to eat unusual foods using 103 Dutch beef consumers on beef burger patties. The burgers were labelled to contain beef and unusual ingredients (frog meat, mealworm) and the willingness of consume burgers was predicted by food appropriateness and not sensory liking, gender of food neophobia. The sensory experience played a role in accepting the food but not enough when cultural inappropriateness is involved.

2.5 Summary of literature

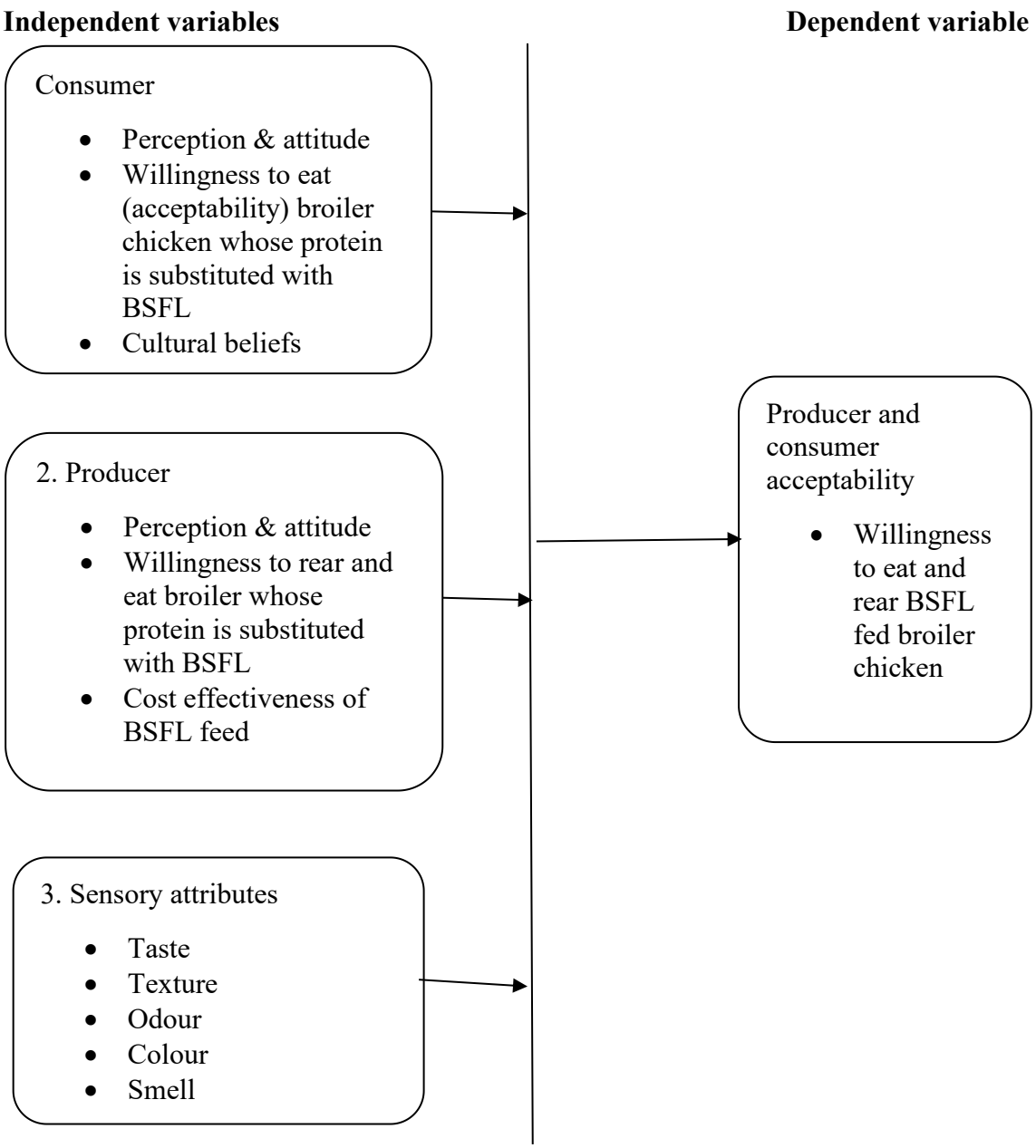
Poultry producers are consistently engaged in the exploration of novel technologies or distinctive inputs that have the potential to decrease production costs and enhance revenue generation. Nonetheless, these specific products lack an established market, posing difficulties in accurately projecting their potential demand within the industry. Consequently, the process of estimating demand from poultry producers relies heavily on gauging their indicated acceptance and adoption of these innovations (Chia *et al.,* 2020).

2.6 Conceptual framework

The diagram below illustrates the conceptual framework showing the relationships between independent factors, producer and consumer perception and attitudes and the overall acceptance and adoption of the broiler chicken whose conventional protein feed is substituted with BSFL.

Figure 2.1:

Conceptual framework



Source: (Researcher, 2022)

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research methodology that was used for the study. Specifically, the section outlines the research design, study area, study population, sampling, data collection and analysis and ethical considerations.

3.2 Research Design

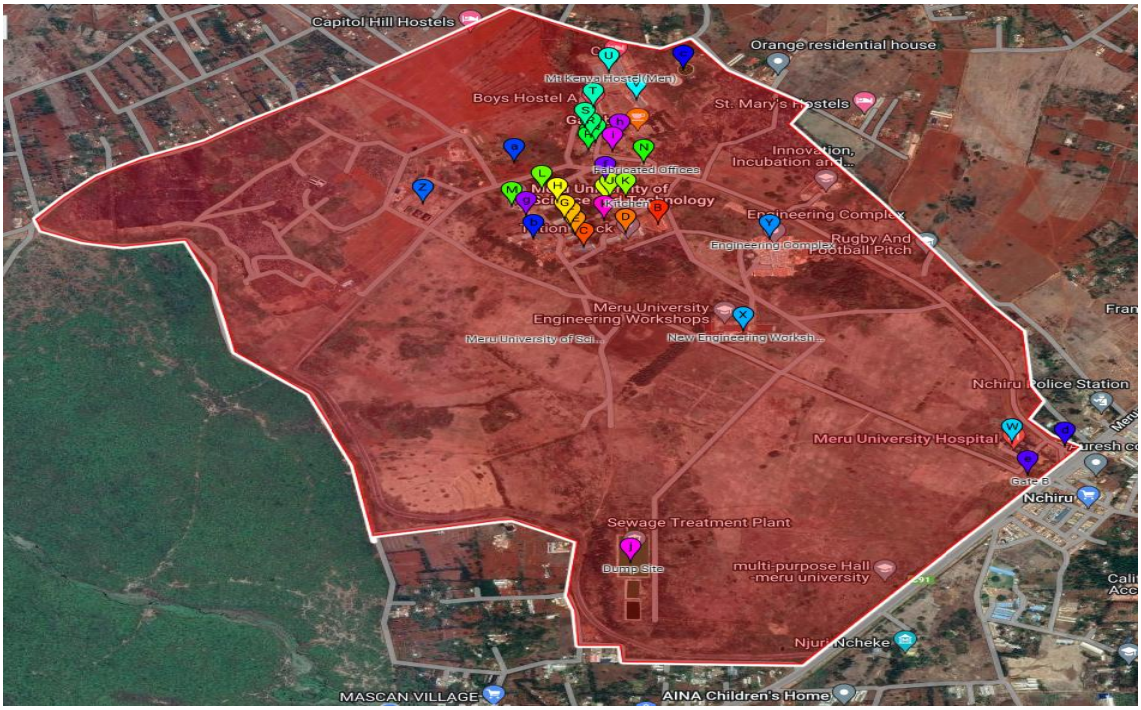
The design used ensured simultaneous gathering of both qualitative and quantitative data. The use of mixed methods facilitated data triangulation and enabled the researcher to enrich the data pool with viable explanation (Bulinda *et al.,* 2023).

3.3 Study area

The study was conducted in Meru University of Science and Technology (MUST) main campus during academic year 2021/2022 semester one. The area is in Tigania West Sub-County in Meru County, Kenya. MUST is situated 15km from Meru town along the Meru-Maua Road at geographical coordinates 0.1349° N, 37.7084° E (See Fig 3.1). The school has approximately 10,000 students (UU-A, 2022). The study area is representative of other communities in the Country being an agricultural upcoming and busy cosmopolitan urban settlement. Tigania West boasts a rich cultural tapestry where many races are typically accommodated but is primarily inhabited by the Ameru people who have distinct traditions, languages, and social structures. This cultural diversity offers a unique opportunity for research which could shed light on the dynamics of

Figure 3.1:

Map of the study area



3.4 Study population

The study involved a broad cross section of consumers including members of staff and students who were on campus during academic year 2021/2022 Semester I. A subset of the consumers were third- and fourth-year students as well as lecturers from School of Agriculture and Food Science were part of conducting sensory evaluation of the broiler chicken. BSFL were reared in troughs at the Sanitation Research Institute (SRI), MUST as shown in (See Fig 3.2). The solar dried BSFL were then ground at a commercial posho mill then used to obtain the experimental dietary treatments for the study. The study also targeted producers (farmers) who were drawn from Tigania West Sub-County. Through the ministry of agriculture, livestock and fisheries, the State Department Sub-County officer linked the researcher to the farmers in poultry production because they had prior knowledge on insect-

based feeds. To comprehensively understand the value chain and resource recovery in detail, the producers were involved.

Figure 3.2:

BSF rearing trough at SRI

Source: (Researcher, 2022)

3.5 Sample size determination

The sample size was calculated using the Fisher's formula

(n = $\frac{z^2 pq}{d^2}$)

where;

n is the desired sample size,

Z = 1.96 (normal standard deviation at 96% confidence interval)

P= proportion of the population with the problem (0.5) when the population with the problem is unknown

Q = proportion of the population without the problem (1-p)

d= margin of error (taken to be 0.1 for this study)

n= $\frac{(1.96)^2 * 0.5 * 0.5}{(0.1)^2}$ = 96 participants

Table 3.1:

Sample size distribution

Category	Population	Sample targeted
Consumers (students)	10,000	42
Producers (farmers)	1,000	23
Panelists	30	8

Source: (Researcher, 2022)

The study involved 42 consumers, 23 producers and 8 panelists, they were involved due to their knowledge based on insect derived products.

3.6 Sampling techniques

Simple random sampling technique based on voluntary recruitment was employed to select participants (consumers) for the quantitative study who were students or trainers from MUST. MUST is among the renowned BSFL technology users and the targeted participants understood what the Technology was because they had interacted with it in the Institution. On the other hand, producers, who were broiler chicken farmers from the host constituency, Tigania West, were selected using purposive sampling technique to participate in a focus group discussion. The producers selected for participation because they had interacted with the BSFL technology and understood the subject matter. It was believed that the information obtained from the farmers was reliable. The panelists evaluating the sensory attributes of broiler chicken were lecturers who were purposively selected from the Department of Food Science in MUST. The lecturers had well developed sensory abilities to detect the desired attributes of chicken.

3.7 Inclusion and exclusion criteria

Producers participating in the study were residents of Tigania West practicing broiler poultry production. The farmer targeted were those who had reared broiler chicken using BSFL. Farmers from other parts of the country were excluded from participating in the study. The consumers were students in session for the academic year 2021/2022, semester 1 or members of the university staff who were willing to participate in the study. The study excluded students who were not in session. Consumer panelists participating in the sensory evaluation were experts from the department of food science because they had well developed sensory abilities to evaluate the attributes of the broiler chicken such as taste, smell, colour and texture. Participants with allergies and medical conditions were excluded from participating in the sensory evaluation.

3.8 Data collection

3.8.1 Structured questionnaires

Quantitative data was collected using structured questionnaires (See Appendix A) which were distributed to consumers (students and trainers) from MUST. In structured queries, closed ended response categories were provided to respondents. Closed ended questions helped in saving time when answering the questions (Fraley *et al.,* 2011). The questionnaires consisted of demographic data, perception and attitude of participants on faecal sludge-derived products. Using an online link that was posted on generic social media groups and WhatsApp groups within the university, recruitment of consumers was done voluntarily. Participants were presented with an introductory message before being asked whether they agreed to sign up and participate. This greatly eased the process of reaching out to them for the sequential activities of data collection. A different structured questionnaire was also

distributed to broiler chicken farmers to establish their perception and attitude on BSFL products.

3.8.2 Focus group discussion

Producers were also engaged in two separate focus group discussions (See interviewer guide on Appendix B) with an aim of obtaining in depth information on how comfortable they were with using BSFL technology for chicken rearing. The first group consisted of 10 farmers while the second group had 9 farmers.

3.8.3 Sensory evaluation

Students and trainers with well-developed abilities to test and judge the attributes of food, sourced from the Department of Food Science were involved in a chicken testing activity. They tasted and examined the broiler chicken fed with BSFL feed and described their attributes in terms of taste, tenderness, smell and appearance.

i. Sensory experimental setup

Unraveling the intricate link between BSFL-fed broiler chicken and their sensory perception necessitates a meticulously designed experiment. This experiment focused on isolating the influence of BSFL-fed chickens on sensory characteristics, which contributed valuable insights on the final taste and texture as experienced by consumers. The experiment was conducted in 2021 following established guidelines for sensory testing. The guidelines as per 2021 stated that cooked samples, unless they are evaluated right away, should be stored in a tight container, allowed to cool to a temperature that is comfortable to taste, and then kept warm. Items that have already been prepared, such cooked shrimp, ought to be slightly reheated.

The product's appearance should be noted, and any unique aspects should be noted by the assessor. It is important to evaluate the smell and note its strength and characteristics, especially for odd smells like chemical taints. Since some components (such as low levels of breakdown or fuel contamination) can only be identified by tongue, assessors should be encouraged to taste cooked samples. The taste of a sample in the tongue can provide more information, but it should also support the judgment made based on smell). Including consulting with sensory science experts from universities, research institutions, or private companies with experience in sensory testing

ii. Sample preparation

Broiler chickens were sourced from SRI, an experimental farm at the university. The chickens were reared under three treatment units. The treatments units were the conventional broiler chicken (D0), 50% BSF and 50%soy (D2) and lastly was the 100% BSF (D4). The feeds used were prepared as per the formula by Oyoo *et al.,* 2023. Three broiler chickens from the treatment units were selected randomly for conducting sensory evaluation and slaughtered at 10 weeks of maturity after 24 hours withdrawal without feed. Following the guidelines set by the Kenyan government and other relevant authorities on slaughtering of animals (governing the licensing, oversight, and control of slaughterhouses and other locations where meat is processed for human consumption in any way; this includes maintaining technical standards for health, sanitary, and hygiene standards in these locations and in consultation with the Minister in charge at the moment). Slaughter animals must undergo post and ante-mortem inspection to ensure that wholesome food reaches consumers. Veterinary officers were invited to the institute where the chickens were reared.

A pre-slaughter inspection of the chickens was conducted to assess their health and fitness for slaughter. For inclusivity, Ibrahim *et al.,* (2014) recommends that broiler chickens be slaughtered according to Islamic rules (Halal method) and non-Islamic rules (non-halal method) to avoid limitations. In the presence of the Veterinary Officers, the internal organs were removed and inspection was done on the chicken carcass to ensure it met food safety and meat quality standards (Meat testing in labs includes stability, shelf life, residue identification, meat grading, and freshness control. Meat quality control involves monitoring every step of the process, spotting irregularities, confirming, and upholding established protocols).

The broiler chickens were then sacrificed by cutting through the vein located at the front of the neck, just below the head using a sharp knife. The chicken immediately bled out to ensure efficient blood drainage. The chicken carcass was then passed in a basin with hot water, which was used to loosen the feathers, making it easier to pluck. The chicken was then cut to obtain the breast muscles which have sufficient meat quantity (Oloo *et al.,* 2018) were then labelled to keep track of the dietary treatment unit.

The boneless, skinless breast muscles were the sample for the evaluation. The sample was prepared at the food science laboratory at MUST which provided a neutral evaluation space free from odors and distractions. The breast muscle (pectoralis superficialis) was wrapped with an aluminum foil and a label then put in a zip lock bag. The sample was cooked to an endpoint of 78°C for 15minutes in a zip lock bag in a water bath. The cooking temperature profile was monitored during cooking by using a thermometer. The samples were left to cool for 15 min, allowing them to equilibrate to ambient temperature.

Three chicken from each pod adding up to 9 chickens from each treatment diets were randomly selected in triplicates for the sensory evaluation including discriminatory and affective test as described by Oloo *et al.,* (2018). Eight panelists took part in the sensory evaluation as a figure within the range of 8-12 sensory evaluators as suggested by Ackbarali and Maharaj (2014).

iii. Laboratory set up

At the laboratory, each panelist had an individual booth setup, provided with a fork, knife, questionnaire and a bottle of drinking water and a glass of water to rinse their mouths out between each sample to remove all traces of the previous sample. They were also seated in such a manner that they could not communicate with each other and in a room which was free from distractions and had good lighting and ventilation. The sink was centrally located for mouth rinse. The breast broiler chicken samples were cut into cubes of approximately the same size (1cm square). The samples were labelled by a random three-digit blinding code. Three samples were presented to each panelist on white evaluation plates labelled accordingly.

Samples were served in a completely randomized order since more than one sample was to be assessed. This was to ensure that the assessors do not receive the samples in the same order, since that would introduce a bias. Panelists were instructed to evaluate all sensory attributes; smell, taste, colour and tenderness as they filled in the questionnaires (See Appendix C) on discriminative test and affective test to determine the different sample and also rank the sample in a range. The affective, also known as preference or hedonic tests, screens a sample to determine the acceptability of a product or if one is preferred over the other. A modified five-point hedonic scale—1 representing extreme dislike, 3 representing

neither dislike nor like, and 5 representing extreme like—was used to conduct the assessment. Samples prepared from the control dietary treatment unit D0 was denoted by code 753, D2 by code 968 and D4 by code 396.

3.9 Pretesting Research Instruments

Pretesting of the consumers' instruments was done on students by administering the instruments to 42 students (3rd and 4th years) of targeted respondents by the researcher. For sensory evaluation, the study was piloted with 10 randomly selected students from Pure and Applied Science Department students in MUST pursuing Bachelor of Science Food Science and Technology to ensure questions were clearly phrased. The broiler chickens were slaughtered at 7 weeks of maturity after maturity. The chickens slaughtered were then prepared to test all the instruments before the actual data collection exercise.

The researcher then sought opinions from experts in the Food Science laboratory. Respondents (42 students) were randomly selected to participate in pre-testing of the research instruments and excluded in the final study. This helped the researcher to assess the study feasibility and respond to possible deficiencies in instruments for data collection (Aliff *et al.,* 2017;Majid *et al.,* 2017). The process helped to identify any ambiguity or inconsistencies in the wording and structure of the questionnaire. Participant feedback and expert input were incorporated into refining the instruments, enhancing their clarity and relevance. The validation process contributed to the credibility of the study's findings. Through pretesting the validity and reliability of the questionnaire was ascertained. Errors and pitfalls were identified and addressed.

3.9.1 Reliability and Validity of Research Instruments

Instrument validity was used to assess the extent to which the employed data collection instruments produced constant outcomes when used over and over again (Johnson *et al.,* 2017). To establish the dependability of study tools, a test re-test was carried out by initially distributing them and scoring the responses afterwards. From the test re-test results, reliability coefficient was determined using Cronbach's Alpha Coefficients. The dependability test recorded 0.84 factor indicating higher dependability. If a dependability factor merit attained is over $r>0.70$, the research viewed this as a show of higher dependability. But, if the merit was less, then the study tools were redone and the process repeated until the needed r value is 0.70 and above. The instruments were thereafter tested for validity and afterwards printed for use during fieldwork. Cronbach's Alpha of 0.84 suggested a high level of internal consistency, indicating a high reliable instrument. This suggested that the instrument is suitable for measuring the intended construct in the research study, and researchers can have confidence in the reliability of the instrument and the validity of the data obtained from it.

Instrument validation aided in drawing meaningful, precise and justifiable conclusions from result scores. Experts tested the instrument's validity via judgments. Determination of instruments was done by peers in research and supervisors on content appropriateness for the success of the study. The supervisors ascertained the tools' suitability in addressing the need for the study. Lastly, validity of collected information was done by administration of the instruments to respondent personally along with qualified staff assistance to ensure validity (Johnson *et al.,* 2017).

3.10 Data Analysis

It was important to carry out data analysis for the collected data. The data analysis process involved data clean up, explanation and reduction. The process of data clean-up involves editing, tabulation and coding in a sequential form with the aim of detecting anomalies in the responses and also assigning numerical values to the responses for further analysis. The data analysis was carried out using Statistical Package for Social Sciences (SPSS) version 26. In the process of keying data in the statistical software, appropriate codes and variable specifications after counter checking were done to ensure that there were no erroneous entries. Quantitative data was analyzed using descriptive statistics like percentages, mean which was a measure of central tendency and standard deviation which was a measure of spread of the data. The data was also analyzed in inferential statistics such as correlations and regressions to show the relationship between variables. Pearson's product moment correlation was used to measure the strength and direction of the relationship between variables. Analysis of Variance (ANOVA) was used to test the statistical significance of the coefficients in the regression model. The producers FGD transcript was analyzed thematically. Data was coded deductively and grouped into themes to meet the study's objectives. The qualitative data obtained was presented in narratives.

3.11 Ethical Considerations

The researcher sought to work with full approval to adhere to the scientific requirements of research. Ethical approval was sought from the national licensing body, National Commission for Science, Technology & Innovation (NACOSTI) through SRI, MUST, and from the university body that gives permission to conduct research, Meru University Research Ethics Review Committee (MIRERC) after which a letter of authorization was

issued by Meru University of Science and Technology (See Appendix D). The researcher presented the letter to the National Commission of Science and Technology to be given a research permit. This permit was presented to the Directorate of Food security, Meru County, to gain their authorization for the study to be carried out within their jurisdictions. An approval was issued for data collection.

During the entire process of carrying out this study, the rights of the respondents were respected by the researcher and the field staff. First the respondents were informed of their right to participate or to withdraw participation as participation was entirely voluntary. Then, those who agreed to participate gave informed consent. Afterwards, respondents were informed of their right to remain anonymous as their personal information was entirely anonymized in the study. Respondents were free to answer questions in the instruments without being coached on the desired responses by the researcher. The entire process was done with confidentiality so as to honor the privacy of the participants. After, the instruments were filled and collected, they were stored under lock and key to ensure only the researcher accessed the information. In ensuring anonymity of collected data, any identifiers like participant names will be withheld, and instead, random identification numbers will be assigned during the online data collection process. This method safeguards the privacy and confidentiality of participants while allowing for accurate data analysis and interpretation.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the findings of the study based on the objectives of the study. Specifically, the section presents data on demographic characteristics in terms of gender, age and religion, on acceptability (perception and attitudes of producers and consumers) and sensory evaluation of faecal sludge derived products.

4.1.1 Response Rate

The data in table 4.1 indicates the questionnaire response rate from the respondents who participated in the study. The study targeted a sample size of 96 respondents; whereby 73 questionnaires were administered, 73.7% was obtained from consumers, 79.3% from producers and 80% from panelists making a total response rate of 76%. The high response rate showed a lot of interest and commitment from the respondents towards the research. This showed that the majority responded and therefore enough information was recorded for analysis. Overall, the response rate can be considered to have been very high.

Table 4.1:

Participants response rate

Category	Participants targeted	Response	Percent
Consumers	57	42	73.7%
Producers	29	23	79.3%
Panelists	10	8	80%
Total	96	73	76%

Source: (Researcher, 2022)

The study indicated a return rate of 70.9% which demonstrated that data was collected exhaustively. This response rate is within the rate allowed by academic studies as reported by Zhang *et al.,* (2021) which states that academic studies should have a response rate of above 50% are considered statistically acceptable and reliable (Zhang *et al.,* 2021).

4.2 Demographic Characteristics of Participants

The participants: consumers, producers and sensory panelists were involved in answering questions regarding their demographic characteristics. The identifiable demographic characteristics relating to respondents included gender, age, education, region of origin, feeding habit and religion. The demographic data was necessary because it described the nature of participants.

Table 4.2:

Demographic characteristics of participants

Respondents Demographic Characteristics		Gender of the Respondent		
		Total	Male	Female
Education Level	Primary Level	21%	60%	40%
	Secondary Level	33%	38%	62%
	Tertiary Level	40%	39%	61%
	No Education at all	6%	50%	50%
BSFL Farming Duration in the Area	Less than 5 years	20%	50%	50%
	1-2.5 years	21%	48%	52%
	3-5 years	26%	34%	66%
	5 years and above	33%	47%	53%
Religion	Christianity	91%	41%	59%

	Muslim	4%	100%	0%
	Atheist	5%	40%	60%

Source: (Researcher, 2022)

Table 4.2 shows that out of the respondents, 40% attained tertiary education comprising of 61% female and 39% male, 33% attained secondary education comprising of 62% females and 38% males,21% attained primary level comprising of 60% male and 40% females, and 6% had not gone through education comprising of 50% male and 50% females. In addition, 33% had farmed in the area for 5 years and above, 26% had farmed for 3-5years, and 21% farmed for 1-1.5years and below. The research area was mainly occupied with the people practicing Christianity as a form of religion. For this reason, 91% of the respondents were Christians, 5% were Atheists, and 4% were Muslims.

4.2.1 Gender of Respondents

The researcher sought data on the respondent's gender. The data on gender to understand which gender was more involved in rearing and eating chicken fed by BSFL. It was essential to determine normal distribution on respondents' gender because none of the gender was given preferential consideration in the selection of respondents. The results are as shown in table 4.3 below.

The result in table shows that the majority of the respondents were males at 65.8% and 34.2% represented female respondents. The composition of the respondents by gender indicates that the study satisfies the gender for one third representation. Gender affected the consumption of Black Soldier Fly (BSF) fed chicken through differences in food preferences, health concerns, and attitudes toward sustainability

Table 4.3

Gender distribution

Gender	Frequency	Percent
Female	25	34.2%
Male	48	65.8%
Total	73	100.0

Source: (Researcher, 2022)

From the study, females were more concerned with nutritional content and benefit of the chicken to the body compared to men who were less concerned with trying new foods. Some were afraid because of the consumption because of the health risks. More so women were rooted in cultural norms and traditional diets on food preferences and thus the lower percentage of consumption. The study findings were similar to Nabiswa *et al*. (2023) who reported 15.4% of respondents recorded purchases made by the male head of the family, but contradicted those of Pambo *et al*. (2016), who found that women in Western Kenya made the majority of the decisions about insect meals and Wanjala *et al*. (2023) who also recorded that women were more involved in eating insects in their households. The results show decisions about eating and rearing of chicken fed BSFL were not done collaboratively, male decision-making was more than twice as high as female decision-making. Furthermore, edible insect business involved a significant participation of women (98.6%) and children (92.3%) in the wild collecting of insects (Kusia *et al.,* 2021). Waithanji *et al.,* (2020) focused on attitudes and practices among poultry and pond fish farmers from Kisii, Kirinyaga and Nakuru in Kenya and revealed that women were more involved in poultry farming. The differences could be attributed to that fact that the male head of the household

was supposed to provide the money for the purchases and construction of chicken pods, also women followed the eating preferences of men (Nabiswa *et al.,* 2023).

4.2.2 Religion

Respondents were requested to indicate their religion. Religion aspect was important for this study because religion could influence ethics and eating habits especially animal products. It is believed that believers in Islam religion do not eat pork (Sheikhi & Firoozabadi, 2020) while believers in Hindu religion do not eat beef (Usama *et al.,* 2022). The results of the respondents on the religion characteristics are shown in table 4.2.

The consumption of chicken raised on Black Soldier Fly (BSF) can be greatly influenced by religion as indicated by this present study findings. Dietary rules determine which meals are acceptable in some religions. For instance, eating must be halal in Islam, therefore using insects as sustenance may come under examination (Riyaz, 2023). Similar rules may apply to animal feed under kosher regulations in Judaism (Regenstein *et al.,* 2003; ur Rahim *et al.,* 2022). Furthermore, using insects may raise ethical issues for some Buddhist and Hindu faiths (Barrasso *et al.,* 2020). Thus, adoption and consumption of chicken fed Black Soldier Fly larvae can be influenced by dietary constraints and religious beliefs.

4.2.3: Age

Distribution of Participants according to Age

The respondents were grouped into 3 age brackets. The three age categories comprised of 18-25 years, 26-40 years and 41-55 years. The classification was done to determine whether the age of respondents affected the taste, smell of the samples used in study. The data in table 4.4 below represents the age distribution of the participants.

Table 4.4:

Participant age distribution

Age Bracket	Frequency	Percent
18-25	38	52.1
26-40	27	37.0
41-55	8	11.0
Total	73	100.0

Source: (Researcher, 2022)

The research findings indicate that most of the respondents were between 18-25 years. This group comprised 38 respondents out of 73 which is equal to 52.1%. It was closely followed by age group between 26-40 years at 37%. 41-55 years had the least number of respondents at 11%. The findings implied that most of the respondents were in the bracket of middle class and the consumption and expenditure habit of this group could be affected by several factors which were internal and external. Younger participants (18-25years) were the majority of the consumers and producers of BSFL fed chicken which was attributed by openness and perception to trying new foods compared to older consumers who were resistant and skeptical to trying unconventional sources, which was similar to study by Siddiqui *et al*., (2022). Also, the younger participants were students and might have been motivated by the hunger faced in school. The lower number of adults could be attributed to them being more aware of the health benefits of the BSFL fed chicken as reported by Megido *et al*., (2024).

Regarding the respondents' age and religion there was a significant variation in the frequency of insect ingestion as reported by Hlongwane *et al*., (2021). In fact, it is well

known that some religious beliefs can inhibit entomophagy (Hlongwane *et al.,* 2021) and that education can encourage people to give up eating insect (Pambo *et al.,* 2018). Furthermore, a number of studies have demonstrated that young people's openness is the primary reason why they are more likely than older people to engage in entomophagy (Laureati *et al.,* 2016; Sogari *et al.,* 2019; Ehounou *et al.,* 2018).

A further breakdown on producers specifically indicated that the modal age bracket was 41-55 years at 40%. There were no respondents who had years between 18-25 years. This data displayed the real situation in Kenya where agriculture was mostly practiced by the elderly and not the young generation. These results are in line with Stull *et al*. (2018) who reported that entomophagy is practiced by various age groups, particularly in regions where it is a traditional part of the diet. In countries across Africa, Asia, and Latin America, both children and adults consume insects. Older generations often pass down the practice due to cultural traditions. However, Kusia *et al*., (2021) reported that age and occupation had a substantial impact on insect meal consumption, but neither geography nor educational attainment did. Similarly, Wassmann *et al,*. (2021) correlated willingness to eat insects and reported that age and education were irrelevant in the effecting the willingness to eat insects.

4.2.4: Distribution of Consumers by region of Origin

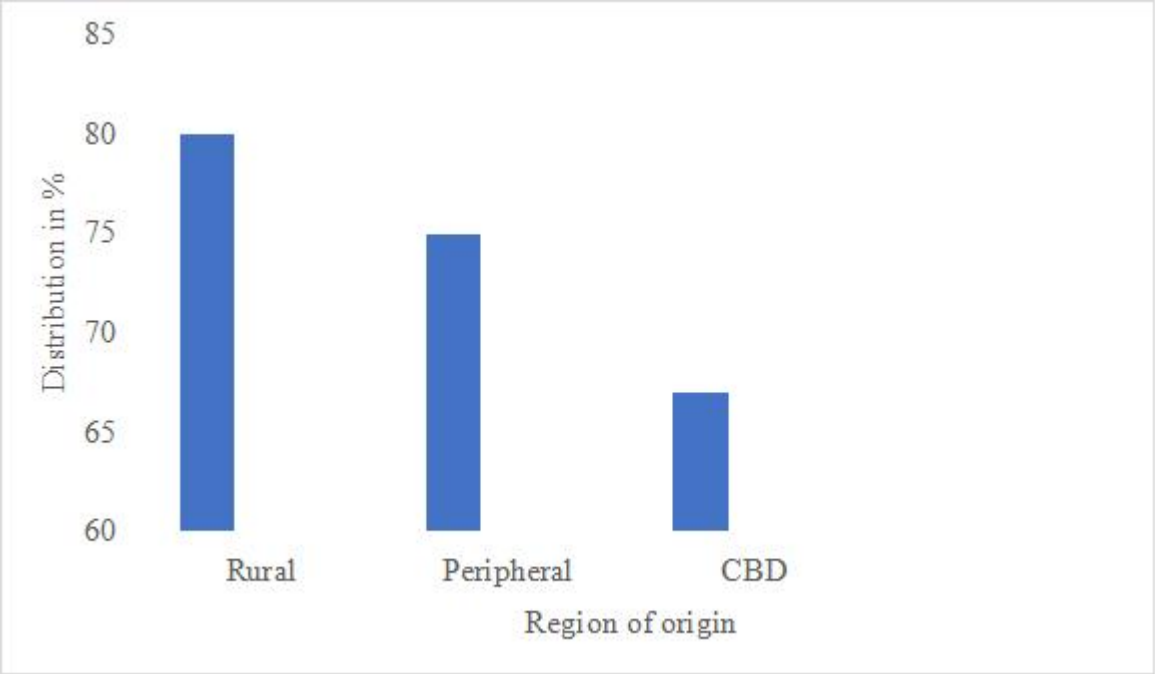
Data on the distribution of consumers by the region of origin was necessary to determine whether the region where participants came from affected their perception on BSFL fed Chicken. The study sought to establish the diverse regions in the county represented by the students and members of staff at the university.

The participants were majorly from rural areas (80%) compared to urban areas. This study findings related to a study by Ngo and Moritaka (2020), consumer preferences for insect

feeds were influenced by cultural and background variations. Those with a rural background were more likely to purchase meat that has been fed insects. This is probably attributed to the fact that rural communities are accustomed to raising chickens and occasionally consuming certain types of insects.

Figure 4.1:

Participant distribution



Source: (Researcher, 2022)

Individuals in rural regions consume more insect-fed chicken than individuals in urban areas do (89.7% vs. 80%) according to Manditsera *et al*., (2018). This can be the result of the rural life often exposed to insects due to the nature of their surroundings. Small poultry owners in rural regions frequently feed their chicken insects and insect larvae due to a lack of resources or the inaccessibility of commercial feed that is high in protein, according to Chia *et al*., (2019). They view insects as a viable alternative to conventional meals high in protein for their chickens.

4.2.5: Distribution of Feeding Preferences by Gender

The study further sought to establish how gender was relating to consumption preferences by the participants, and the results were as presented in Table 4.5.

Table 4.5

Feeding preference

Gender	Vegetarian	Vegan	Non-Vegetarian	Total
Male	17 (30.9%)	2 (3.6%)	36 (65.5%)	55 (75.3%)
Female	2 (11.1%)	0 (0%)	16 (88.9%)	18 (24.7%)
Total	19 (26.0%)	2 (2.8%)	52 (71.2%)	73 (100%)

Source: (Researcher, 2022)

The results indicated that from the study population, 55 (75.3%) were male while 18(24.7%) were females. Further to which contributed higher proportions of all feeding preferences. Vegetarians are people who do not consume animal products while vegans do not consume any animal products(Allès *et al.,* 2017; Appleby & Key, 2016). Non-Vegetarians were meat eaters. Males represented the larger proportion of non-vegetarians at 36 (65.5%) while females were 16 (88.9%). From the table, less women were non vegetarian however, they still consumed insect fed chicken because of women and children fed on the head of households' favorite meal as also recorded by Nabiswa *et al*., (2023).

4.3 Consumer Preferences

4.3.1 Knowledge and Practices

One of the factors that affected demand of BSFL fed chicken could be consumer preferences and taste. It was important to carry out consumer preferences on the study. The data of consumer preferences was collected through requesting the consumers to answer the

questions on sanitation system that they use and containment practices through google forms that was shared through WhatsApp.

Table 4.6:

Consumers Practices

Practices and knowledge	**Frequency**
Sanitation systems used	
Container Based Sanitation	1
Pit latrine	42
Flush toilet connected to a pit	2
Flush toilet connected to a septic tank	4
Flush toilet connected to a bio-digester (biogas)	0
Flush toilet connected to a centralized sewer	3
Compost	0
Bush/open field	0
Containment practices	
Dig new, abandon old	41
Empty and reuse containment	30
Other	2
Comparison between conventional way and BSF technique	53
Better than	18
Same as	2
Inferior than	

Source: (Researcher, 2022)

The results of the questions as shown in table 4.6 indicated that most of the respondents (53%) of participants appreciated BSF technology in treatment of waste. The table also describes the experiences that participants have had with different sanitation systems. Most participants (42%) reported that they used a pit latrine as their sanitation system, which was abandoned when full with only 9% of participants having access to a flush toilet.

When pit latrines were full the most common action for participants (41%) was to dig a new pit and abandon the old one, with many citing examples of how they would use the old pit as a source for growing food. In terms of understanding of the new BSF technology, most (53%) of participants reported that they felt it was better than the existing method of disposing of excreta. The study findings are different to Mkude *et al.,* (2021) who recorded that resident had little knowledge of faecal sludge, resource recovery, and reuse. The residents had a negative attitude towards using the faecal sludge-derived products, except for products that were not directly consumed, such as the biogas and the FS-briquette in Tanzania. In addition, business feasibility of the sanitation derived products including faecal sludge, municipal solid waste-based composition influenced the farmer's willingness to pay $ 0.4 above per kilogram of FSM compost and placed a higher worth on compost-certified products (Danso *et al.,* 2017).

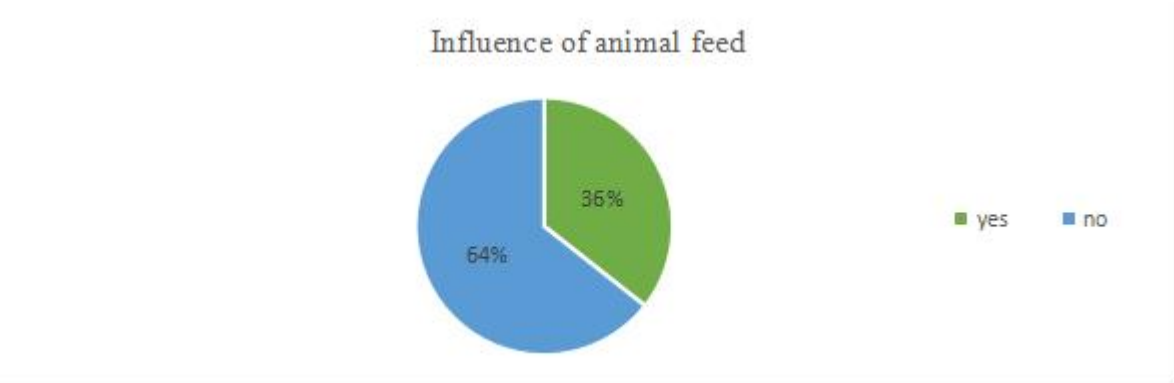
4.3.2: Attitude and Perception

The data on attitude and perception was collected through asking the respondents to answer whether the feed that an animal consumed influenced their acceptability of its product. The results were visualized in Figure 4.2 below.

Most of the respondents answered that the feed the animal consumed does not influence their acceptability of its products. It means that animal feed does not influence 64% of the respondents and only 36% will change their acceptability on animal product when they know about its feeds.

Figure 4.2:

Influence of animal feed towards consumption



Source: (Researcher, 2022)

The study findings differ to Fischer and Steenbekkers' findings where participants were highly affected negatively as they expressed varying degrees of anxiety (Fischer and Steenbekkers, 2018). They noted that some common insects are significantly more acceptable than others, including mealworms, crickets, and grasshoppers. The advantages of insect feeds are not well known to many people because of a lack of information. Consumer groups are made to detest and express worries by educational backgrounds related to nutrition; nevertheless, other research have revealed that consumer opinions of insects as feed remain unchanged despite their recognized nutritional and environmental benefits. (Lammers & Associates, 2019). A study reported fear of trying an unfamiliar product, lack of taste experience, and the belief of low social acceptance were considered as major constraints in popularizing edible insects (Meyer-Rochow & Hakko, 2018); This was despite

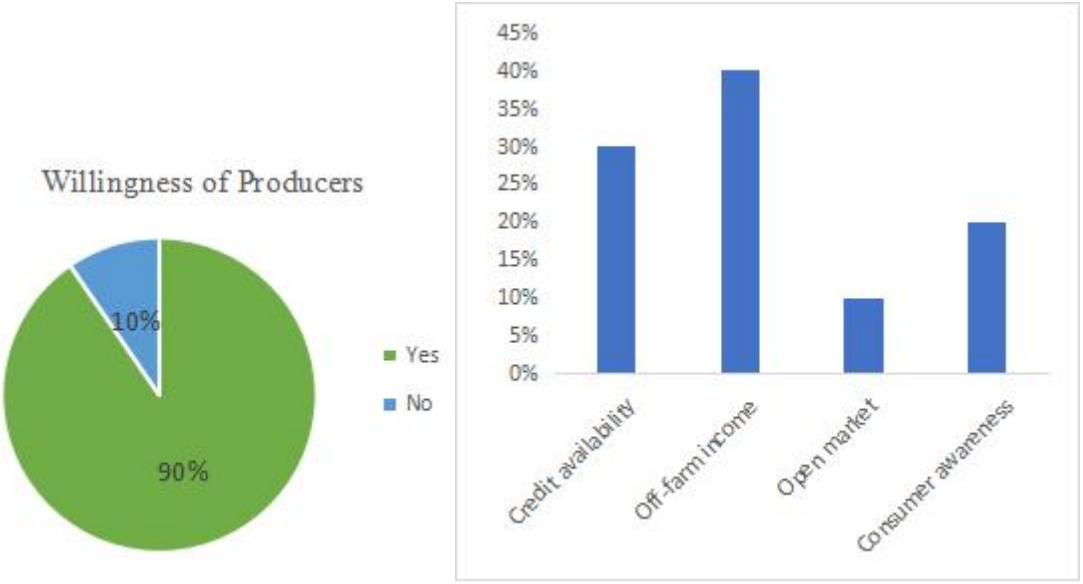
the fact that a greater acceptance was noted for insects without much attention to the species. An additional crucial component of acceptability is accurate labelling. On labelling, Nichani (2005) reported that labelling the eggs of insects was important in limiting unwillingness. However, the notion of labelling was challenged by Balcombe *et al.,* (2016) study which reported that labelling was not sufficient to inform consumers on the insect derived product acceptance

4.4 Producers Willingness to eat BSFL fed chicken

The study then sought to understand the willingness of the producers to consume meat produced using black soldier fly larvae (BSFL) feed. Black soldier fly larvae convert organic waste such as food waste, market waste and or human faeces to rich protein that can be used to formulate chicken feed, dairy feed, and pig feeds. The response for this question is represented by figure 4.3 below.

Figure 4.3:

Willingness to rear and consume Meat Produced using BSFL Feed



Source: (Researcher, 2022)

The results on figure 4.3 showed that 90% of the respondents were willing to consume meat produced using BSFL feeds while 10% did not prefer to consume the meat. The findings indicate that the respondents were willing and preferred to eat meat from animals that were feeding from organic wastes. The higher percentage (90%) of participants willing to consume chicken meat fed on BSFL is most likely due to the fact that a large number of respondents were from rural areas and are accustomed to eating insects. The producers reported that 30% were into this business because of the credit availability, 40% due to off-farm income, 10% due to open market of the by products, and 15% was due to awareness they had about the BSFL. This was in line with the findings of Ngo and Moritaka's report (2020), which noted that the study's respondents had same positive attitudes. The lower percentage (10%) could have been influenced by inadequate knowledge about the benefits of using insects in meals and other alternative protein sources, such as insect feeds, in the diet of chickens. With greater awareness and understanding of the advantages of entomophagy, there has been an improvement in the adoption of insect-based diet (Woolf *et al.,* 2019). Most participants responded that the most likely reason for eating insect foods was curiosity. The most common reason for not eating such foods was disgust (Penedo *et al.,* 2022). Similarly, Ivorians (Ehounou *et al.,* 2018) and Zimbabweans (Manditsera *et al.,* 2018), one of the primary justifications for eating insects is their mouth-watering flavor. The research area's cultural values surrounding particular insect species also play a role in the persistence of insect ingestion from generation to generation.

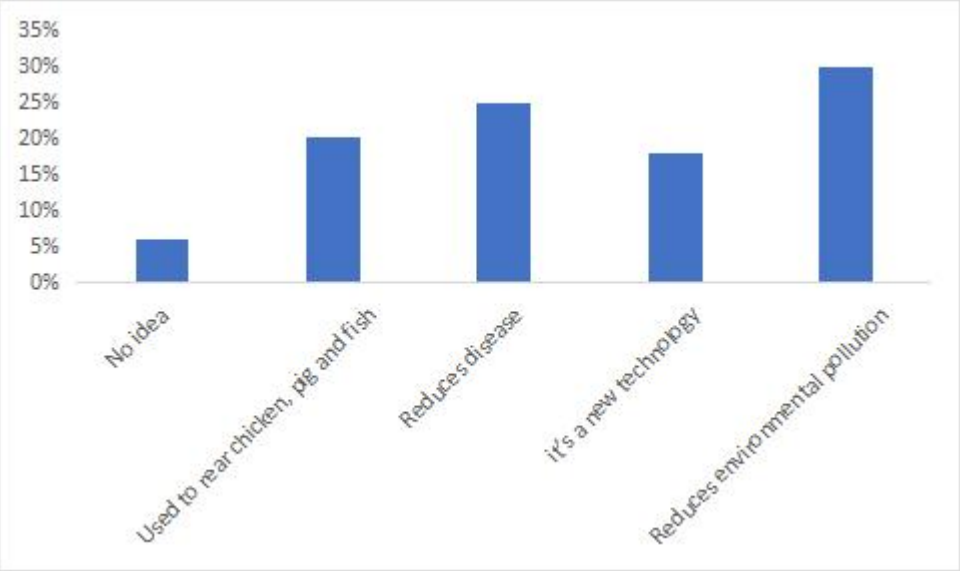
4.4.1 Producer Perceptions and attitudes

Perceptions encompass the beliefs and thoughts and understanding about a product, whilst attitudes refer to a person’s actual feelings about that product and their attitude towards it.

These two aspects influence decision making around food intake. When new foods are brought to market a lot of time and money is invested in the production process, however, often the attitudes of potential future consumers are neglected, even though positive attitudes towards a food are essential if consumers are to purchase the product. This would be particularly important for products that could be perceived as disgusting because of their association with human waste previously in the food production process. The participants explored producers who would be interested in rearing these animals as well as eat the meat.

Figure 4.4:

The attitudes and perception of producers on using BSFL technology



Source: (Researcher, 2022)

The majority (94%) of study participants had a positive perception of this chicken and were willing to eat them, according to the findings. With averages of 94% willingness, the perception statement on the environmental health, reduces diseases and usage in rearing chicken, fish and pig was the most scored. This is consistent with other survey results

(Nichani, 2005; Onyango *et al.,* 2006) showing that consumers' top concerns are food quality and nutrition.

Producer perception on insect-fed chickens was positively impacted by important determinants such as credit availability, off-farm income, open market as a purchase channel, and consumer awareness of the use of insects in animal feed. About 20% of the consumers knew that insects are a source of protein in chicken feed. To enhance findings beyond socioeconomic considerations, more research should examine how consumers perceive novel food products. A study by Gunya *et al.,* (2019) on farmers willingness to consume chicken fed on earth worms was greatly influenced by chicken ownership. However, another study on the farmers' perception on the health risks associated with rearing of earthworms affected the uptake (Gunya *et al.,* 2019). Furthermore, Weinreis *et al*. (2023) on 517 Germany farmers on their willingness to use insects in livestock farming showed that willingness to adopt insects depended on the psychological, personal and farm structural variables while age, neuroticism and use of available resource were the major limitation of the use of insect-based foods.

The farmers (93%) revealed that they felt that consuming broiler chicken may have several benefits in terms of the chicken process and they cited several examples of how the feed could improve farming practices, for example:

"It reduces diseases; because the garbage disposed in the market, if brought this side, will be able to be turned into good use."

"Reducing environmental pollution"

"It can be used in rearing of chicken, pigs and fish"

The farmers discussed how their opinions and education would likely influence decision making on whether to use or not to use BSF based animal feeds as follows:

". If you go and explain to someone, he/she has the urge to eat but he/she has the perception that this chicken has eaten someone's waste. So, it is like eating my own waste thus there are those who won't eat. It depends on how you'll explain to the person"

Among the student population, 52 meat eaters who were non-vegetarians were asked if they felt the chicken would be acceptable. Only 37% said that the feed that an animal consumed influenced their acceptability of the product. On the other hand, 31% of respondents in the study were influenced purely by the taste of the meat they can eat (21) and 73% of all participants reported that the taste of meat was key in informing decision made relating to eating meat. This finding is in line with Ssepuuya *et al*. (2019) who recorded 44.8% and 8.6% of fish farmers and fish traders had ever used insects in their meals. The willingness to use insects such as termites, grasshoppers and cockroaches was positively correlated with farmers perception and familiarity that insects was a good source for nourishment for fish meals (Ssepuuya *et al.,* 2019).

BSFL converted organic waste such as food waste, market waste and or human faeces to rich protein that could be used to formulate chicken feed, dairy feed and pig feeds. About 93% of the participants stated that it was okay to consume meat produced using these feeds against 5 participants who said that it was not. This was shown when producers were probably deterred from consuming insect-fed chicken meat due to their worries about its safety. It was once believed that foods containing insect components were the cause of allergies and illnesses. For instance, the significance of acquainting customers with insect feeding, exposing them to foods on a regular basis will minimize and eventually eradicate

bug aversion. Gunya *et al.,* (2018) claim that a large number of consumers were reluctant to accept meat from insects-fed animals because they are unaware of the basic advantages of insect feed. Similarly, respondents rearing exotic chickens commercially are not easily convinced to take up new ideas of feed (Marra *et al.,* 2003). The farmers believed that insects are good source of protein in poultry feeds. (Sebatta *et al.,* 2018). Furthermore, a study by Odinya *et al.,* (2022) on farmers intention on use of insect-based feed in feeding the dairy cattle reported that 11% of farmers were aware of the use of insects as source of protein in livestock production and 76% were willing to apply insects as an alternative source when made available. Sebatia *et al.,* (2018) reported that over 90% of the farmers were willing to use insect-based foods due to its performance, feed versatility, social acceptability and purchase decisions, off-farm income, education, wealth status and awareness. Therefore, disseminating information about insect feeds to the general population is essential to altering consumer perception (Ballitoc & Sun, 2013). Nonetheless, a large number of customers in our survey acknowledged that they have experience feeding insects to hens.

The majority of farmers reflected on the benefits of using Black Soldier Fly Technology (BSFT) over their conventional practices. The farmers described the direct benefit from recycling treated human waste and reflected on the value addition in terms of income and nutrition, attracting farmers into closing the loop of circular economy in sanitation. Farmers also described a number of barriers between them and the knowledge that would boost the practice of recycling both the human excreta and the organic waste that eventually pollutes the environment if not treated well. The benefits and drawbacks of using BSFL fed chicken were grouped and themes were developed as discussed below:

4.4.2: Circular economy and reduced farming costs

Farmers unanimously cited the ease of adopting this technology since it required simple structures (cages) to be constructed and very minimal labour. The farmers highlighted a number of benefits over use of the BSF technology in faecal waste management including but not limited to reducing cost of production in commercial feeds.

"If you use the BSF you cut cost, it is business."

4.4.3: Importance of Credible information and education

The farmers discussed how different opinions would shape perceptions of the BSF technology and the importance of education to shape decision making on acceptance of BSFL fed products:

"If you go and explain to someone, he/she has the urge to eat but he/she has the perception that this chicken has eaten someone's waste. So, it is like eating my own waste thus there are those who won't eat. It depends on how you'll explain to the person"

Lacking credible information was discussed in depth showing challenges faced by the communities. Politicians were greatly impacting the farmers negatively bring negative connotation to new inventions. Farmers asserted having wrong information about the black soldier fly. Most impact was from political influence. Their concerns included enhancing their knowledge from credible sources of information. Farmers gave credit to the sanitation research institute for enhancing their knowledge on dealing with faecal waste and promoting a circular economy.

4.4.4: Knowledge about BSF technology

The data on the value of experience was generated through asking the farmers to answer the question on knowledge of using BSF technology and benefits they have achieved through

the use of the technology. Most of the farmers mentioned that it was difficult to access the new technology since it was a novel and they were not conversant with its mode of operation. One respondent said:

“We are finding it a bit difficult but just because we haven’t mastered it. If we get into it, it’s good.”

After comparison of BSF technology and the biogas, all waste was identified as a resource that would be recycled and taken back to the farm after utilizing the waste to get energy. Farmers did not have enough information about black soldier fly technology just as recorded by Bulinda *et al.,* (2023) on farmers awareness on the potential of insect farming as an ingredient in livestock feed and 44% of the farmers were aware of using black soldier fly in feed industry however, the results were affected by age and education.

Having a central rearing unit for adults to minimize on resources (time, labor, and infrastructure) in production of eggs. They also agreed to a suggestion that they pool resources and set up an adult cage unit where they can source the larvae to later implement in their communities.

“BSF has many components because if you have these worms, you can feed different animals and finally it will go to the farm and I will use it again. It is a kind of recycling because from the worms it goes to the chicken or cattle, I take milk and the waste of the chicken goes to the farm. Using the waste, it will also help me in cooking. You don’t use a lot of energy.”

“Adult unit as a group such that you just go and pick the luggage and go and another one the same; but from a central point.”

4.4.5: Influence of Traditional practices and experience

Farmers report revealed they were very willing to consume the chicken that was closely related with human faeces. They compared it to traditional practices like consuming termites and rearing free range chicken:

"If you look at what is called free range, if a child poops there, the chicken eats. Chicken eats snake. If you kill a small snake, it swallows whole of it. So, if you kill the chicken for a meal, will the snake be inside there?"

Majority of the farmers suggested having community agents to sensitize members of the community as a way of doing away with rumours and having agents in the communities as ambassadors of change would promote uptake of consuming insect fed chicken. This is also reported by Hartmann *et al.,* (2015) on the cultural comparison on willingness to consume different insect-based foods (processed, baked or unprocessed) mainly the neophobia on consumers' willingness and German were willing to eat processed insect-based meals than unprocessed foods which was somehow affected by neophobia, social acceptance and taste expectations. The participants were willing to consume insect meals after they had been made aware of the benefits.

4.5 Regression on consumer preferences

The perceptions and attitudes of potential consumers towards eating broiler chicken whose protein feed has been substituted with BSF in Kenya was compared through regression of perception and attitudes of potential consumers and the feeding on broiler chicken. A linear regression analysis was used to test the hypothesis at a confidence level of 95%. Feeding on broilers of consumers were regressed against perception and attitude to establish the

goodness of fit, overall significance and significance of the model coefficients. Table 4.8 shows the regression analysis results.

Table 4.7:

ANOVA Table-Consumers

Source	SS	DF	MS	F-Distribution	Sig.
Regression	63.842	1	63.842	18.351	0.00[b]
Residual	250.514	72	3.479		
Total	314.356	1			

Source: (Researcher, 2022)

The regression analysis results showed that the coefficient of determination is 0.203. It means that 20.3% of the variations in feeding on broiler was explained by attitude and perception. ANOVA table was used to test the overall significance of the regression model. The ANOVA table shows that there is a significant influence with an F-statistic of 18.351. Therefore, it implies that the regression model is highly statistically significant at 5% level of significance. Based on the findings on the coefficient table, we conclude that the attitude and perception had a positive influence on producers and consumers which is similar to a study by Rozin and Fallon (1980) which reported that visual appearance of the BSFL food triggerred disgust-based food rejection. A study by Martins and Pliner (2006) reported that perceived mouth feeling and texture properties of the food led to food being rejected based on disgust. Tan *et al*. (2015) traced the socio-cultural factors affecting the acceptance of insect foods and it was associated with decaying matter.

Table 4.8:

Coefficients

	Unstandardized coefficients		Standardized Coefficients		
Consumer	Beta	SE	Beta	t	Sig.
Constant	1.117	0.242	0.435	4.618	0.000
Perception and attitude	0.595	0.063	0.354	9.450	0.000
Producer					
Constant	0.483	0.392	0.534	1.234	0.218
Attitude of potential producers	0.735	0.099	0.452	7.405	0.000

Source: (Researcher, 2022)

Correlation Analysis

Correlation analysis helped in determining the relationship between the variables. This study sought to determine the relationship between acceptability (attitude) of consumers on meat consumption, animal feeds and use of BSFL technology.

Table 4.9:

Correlation

Variable		Animal feeds	BSFL Technology
Acceptability of meat	Pearson Correlation	0.634*	- 0.527*
	Sig. (2 -tailed)	0.000	0.000
	N	73	73

Source: (Researcher, 2022)

The results on the table indicated that there is a positive relationship between acceptability of meat and animal feeds. This is indicated by a correlation coefficient of 0.634. The Pearson correlation coefficient between acceptability of meat and willingness to consume chicken produced using BSFL technology was - 0.527 which means that there is a strong negative relationship. The results indicated that consumers have not adopted the use of BSFL technology as a substitute to protein feeds. The same results were recorded by Ouko *et al.,* (2023) study evaluated the factors that influenced fish farmers awareness on use of black soldier fly as an ingredient in fish meal. The farmers' experience, farmers income and knowledge influence the farmers awareness on BSFL meal. The farmers communication and education helped in improving the farmers awareness on new fish feed ingredients.

Producers appreciated the potential cost savings associated with using BSF-based feed. The reduced need for traditional protein sources and the sustainability of BSF as a feed ingredient were significant factors in their willingness to adopt this approach. The willingness was motivated by feasibility and practicality: Farmers perceived BSF-based feed as a feasible and practical option for poultry production in their local context. They noted

the availability of black soldier fly larvae as a potential protein source and found it logistically manageable. Many local farmers recognized the market potential of broiler chickens raised on BSF-based feed. They acknowledged the increasing consumer demand for sustainable and eco-friendly poultry products and saw an opportunity to meet this demand while diversifying their product offerings. Also, knowledge and training on the best practices for incorporating BSF-based feed into their operations. They emphasized the importance of technical support and guidance in the initial stages of adoption.

A study by House *et al.,* (2016) in Netherlands on consumer acceptance of insect-based foods reported that the leading factors associated with consumption were taste, price, dietary practices and product availability. Shelomi (2015) also reported that negative factors such as the expensiveness of insect foods lead to passive rejection of the foods. The study focused on consumers in Netherlands on insect-based foods. The participants were motivated to try insect foods due to taste, availability and price (Thrastardottir *et al.,* 2021).

4.6 Sensory Evaluation Characteristics

4.6.1 Triangle Test

Eight panelists were presented with the cooked sample D0 and D4 bearing a three-digit blinding codes on white sensory evaluation plates with 500ml bottled water to rinse after every taste. The codes 526, 265 and 489265 represent the blinding codes issued to the panelists as identifiers during the exercise.

The samples were accompanied with questionnaires to record responses of the triangle test, also referred to as the discriminatory test. The panelists were asked to identify the different samples among the three in terms of colour, smell, texture and taste. The triangle test was

carried out twice in succession to test for consistency. The test was repeated with the same samples coded differently to see if the panelists could detect the difference.

Table 4.10:

Triangle test results set 1

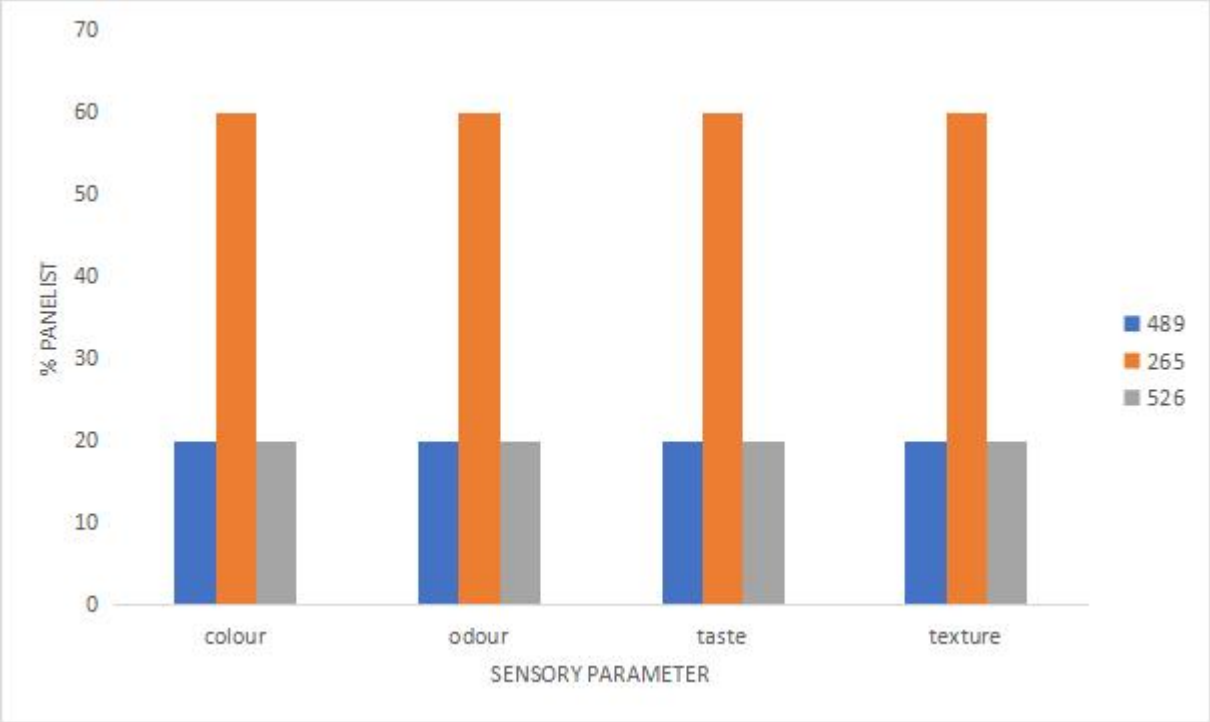
Triangle test	526	265	489
Set 1	D0	D5	D5
Set 2	D0	D0	D5

Source: (Researcher, 2022)

Figure 4.5 shows the results from the triangle test set 1. The graph presents the % panelist that indicated the sample was different from the other two in terms of colour, smell, taste and texture.

Figure 4.5:

Triangle test results set 1



Source: (Researcher, 2022)

In terms of colour, the sample coded 265 was perceived by 60% of the panelists as different from sample 489 and 526 in terms of colour. D4 was indicated to be dark reddish-brownish in colour compared to the rest.

One panelist stated, “D4 did not seem as white as the rest.”

Another panelist in the subsequent triangle test stated, “Colour 489 had an almost brown colour as opposed to the other two.”

With reference to smell and taste sample 265 was perceived by 60% of panelist as different compared to the other two samples in terms of smell. Sample 265 was indicated as not smelly as the others or has lost the chicken smell. Additionally, sample 265 was perceived by 60% to be different on taste compared to the other samples. It was perceived as tastier

compared to the others. One panelist also added that, "*489 had a slightly likeable smell and was more fibrous and had a more tender texture as opposed to the rest."*

For texture, sample 265 was recorded by 60% of panelists as different in terms of texture. It was perceived as soft and tender compared to the other samples.

One panelist recorded that, "Sample 265tasted softer and tastier". The panelist added that "the texture of 265 had a softer texture as opposed to the rest that were tougher'

Fig 4.6 below presents the data results from triangle test results set 2. The graph shows a presentation of the % panelist that indicated each of the samples to be different from the other two in terms of colour, smell, taste and texture. The different samples were code 265 in set 1 and code 489 in set 2, above half of the assessors were able to perceive differences and identify the odd sample. The test was also used to screen the ability of the panelists.

Figure 4.6:

Triangle test results set 2

Source: (Researcher, 2022)

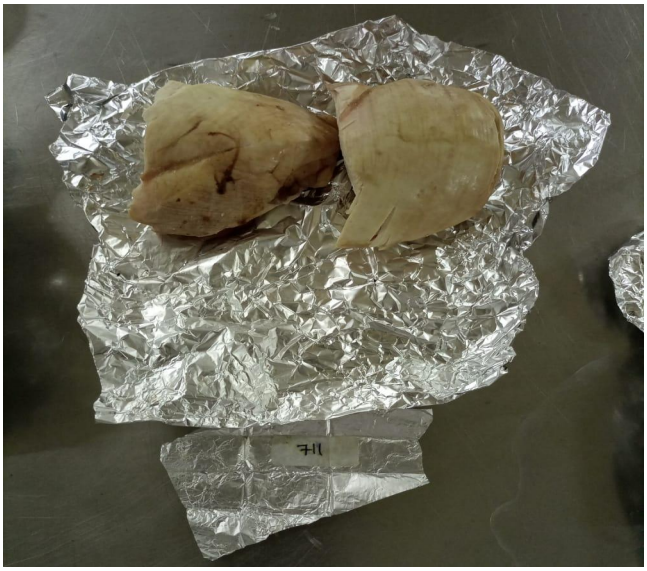
The panelist gave labelling the chicken a good score, making it another significant factor. This suggests that product labels are necessary to let customers know about the section of chicken meal part. Sensory evaluations conducted in this study demonstrated that broiler chickens fed with BSF-based feed exhibit distinctive sensory attributes that are often preferred over traditionally raised chickens. These attributes include improved taste, texture, and overall eating experience.

4.6.2 Affective sensory test

These tests are mostly used to establish the consumer acceptability for a particular product through liking and disliking. Sharif *et al.,* (2017) recommends use of affective tests in the food industry to determine liking and disliking of consumers, willingness to consume a product and their tastes and preference of one product over another.

Figure 4.7:

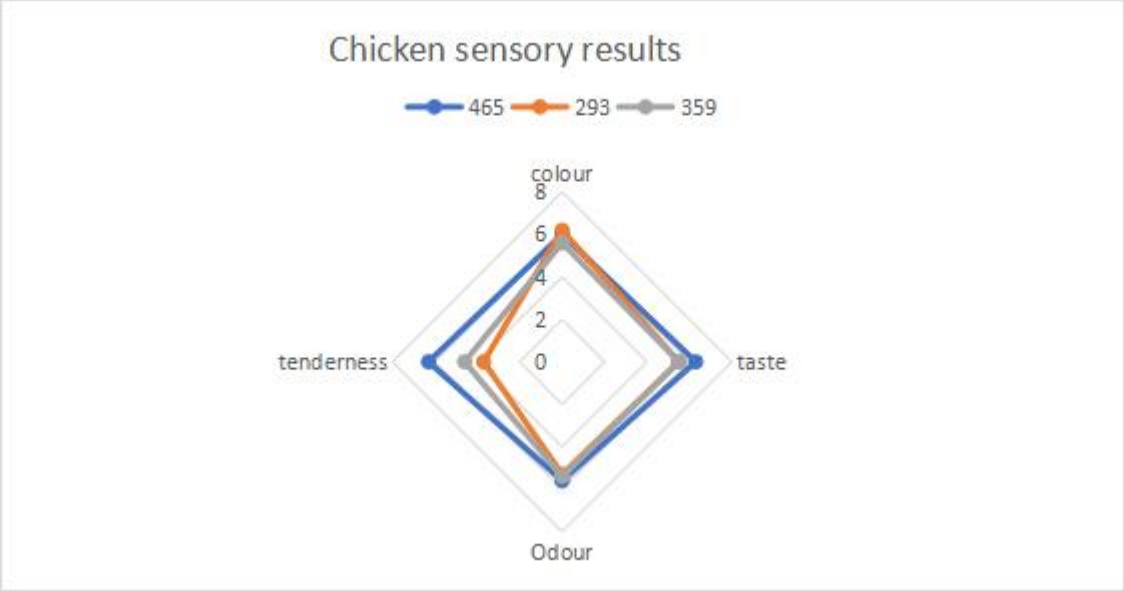
Cooked sample



Source: (Researcher, 2022)

Figure 4.8:

Affective tests results on a spider chart



Source: (Researcher, 2022)

Meat tenderness is one of the very most important factors for customer's acceptability (Sakhr & El Khatib, 2019). The cooked chicken samples were presented to 8 panelists to rank them on a scale of 1-5 on the following sensory parameters: colour, smell, taste and texture. On colour; 1 denoted extremely dark and 5, extremely light. On the smell and taste the scale of 1 denoted dislike extremely while 5, denoted, like extremely. On texture, 1 denoted extremely tough while 5 denoted extremely tender.

Table 4.11:

Sensory evaluation results

Sensory Parameters	Scale	DO	D2	D4
colour	light	75%	63%	0%
colour	just right	13%	38%	38%
colour	dark	13%	0%	63%
smell	like	38%	63%	75%
smell	neutral	0%	0%	0%
smell	dislike	63%	38%	25%
texture	tender	63%	63%	63%
texture	neutral	13%	0%	0%
texture	tough	25%	38%	38%
taste	like	50%	88%	88%
taste	neutral	25%	13%	13%
taste	dislike	25%	0%	0%

Source: (Researcher, 2022)

Referencing colour, consistent findings where BSF-fed chicken often have different coloration, sometimes darker due to higher fat content or different feed ingredients. Adult BSFs have a bronze abdomen and females having a reddish brownish colour (Mertenat *et al.,* 2019). Evaluating smell, mixed results used in some studies found that BSF-fed chickens have a stronger or distinct odor, while others note no significant difference. In terms of taste generally, BSF-fed chickens are found to have a different taste, often described as richer or more umami to mean pleasant savory taste. However, for texture in mixed findings, some

studies report BSF-fed chickens as having a firmer or tougher texture, while others find no significant difference or even a more tender texture.

Surprisingly, study findings showed a high overall satisfaction with BSF fed chickens by panelists who highlighted positive attributes like improved taste and overall eating experience. Consumer acceptability often varies, but many studies report a positive reception of Black Soldier Fly fed chickens due to its unique taste and nutritional benefits. Sensory evaluations demonstrate that BSF fed chicken's shows unique and often preferred sensory attributes. Panelists consistently preferred BSF fed chickens for taste and texture. Various studies highlight the potential of using Black Soldier Fly feed to improve the sustainability of poultry production while enhancing meat quality. In a study by Schiavone *et al.,* (2017), used a larger panel and included different sensory evaluation methods found out BSF fed chickens had a darker colour and stronger flavor, which aligns with the current study.

Some studies indicate initial consumer hesitancy due to unfamiliarity with insect-based feed, but acceptance grows with awareness of environmental and nutritional benefits. Study by Dalle Zotte *et al.,* (2019) included a detailed nutritional analysis alongside sensory evaluation where BSF-fed chickens had distinct taste and odor, with some consumers preferring the richer flavor. Study by Bovera *et al*., (2018) which focused on a broad range of sensory attributes and a larger, more diverse panel found out that BSF-fed chickens had a firmer texture and different taste profile, similar to the current study.

In conclusion, comparing the current study with other research reveals consistent findings in several areas: Sensory Attributes BSF-fed chickens often exhibit distinct differences in colour, odor, taste, and texture. Consumer Acceptability was generally positive, with many

consumers preferring the unique attributes of BSF-fed chickens. The current study aligns well with existing literature, supporting the use of BSF larvae as an effective and sustainable alternative protein source in poultry feed, enhancing sensory qualities that are often preferred by consumers. Future research could further explore long-term consumer acceptance and market potential for BSF-fed poultry products.

CHAPTER FIVE: CONCLUSION, RECOMMENDATIONS AND PUBLICATION

5.1 Introduction

This chapter explains a summary of the findings on consumer perception and the willingness to consume a new product. Based on social perceptions and scientific sensory evaluations, the chapter also gives the conclusions and recommendations of the study based on the objective of the study.

5.2 Summary

Our study findings demonstrated that while consuming BSFL fed chicken accounts for a minor portion of overall food intake, it is deeply ingrained in the eating patterns of the individuals studied. As such, the research reported that both producers and consumers' perceptions and attitudes towards rearing and eating BSFL fed chicken played a significant role in determining their willingness to embrace or reject the chicken.

5.3 Conclusions

Consumers from the university student sample displayed an amplified environmental consciousness because the technology is eco-friendly and a significant driver of their positive attitudes towards BSFL fed chicken. Many consumers perceived BSFL-fed chickens as healthier options due to their lower environmental impact and potential for reduced antibiotic usage in poultry farming. Therefore, there is need to define policies to encourage entomophagy either directly or indirectly through meal incorporation in the study area must take into account the various documented motivations for BSFL fed chicken intake. In edible insect collection fields, a variety of synthetic chemical pesticides are used, raising the chance that eating insects feed chicken might contain hazardous residues to public health.

It is consequently advised that low-income groups be able to access and benefit from the development and popularization of edible insect farming techniques.

Producers displayed a positive response to the idea of rearing broiler chickens on BSF-based feed. They expressed a willingness to explore this alternative feed source as it aligned with their interest in sustainable and cost-effective poultry farming practices because of Cost-Efficiency, Feasibility and Practicality, Market Potential, Knowledge and Training. It was clear that the knowledge level concerning consumption of chicken fed BSFL had a major effect on the perception of respondents. The more the respondents became aware of the value of chicken fed BSFL, the more they showed willingness to use to rear and consume it.

Knowledge, attitude and perception significantly influenced the utilization of black soldier fly technology in treatment of waste to be used as chicken meal. The respondents who reported that BSFL-fed chicken was sweeter, and soft, also reported that BSFL technology improves the economy and taste was the main factor that motivated the consumptions of BSFL fed chicken. Therefore, this study confirms that improving knowledge, education and sensitization on benefits of using BSFL technology as feeds would improve attitudes and decrease health risk perception thereby increasing the overall reuse of treated human excreta in farming activities.

The influence of respondents' demographic characteristics like education level, gender implications and religion requires a deep understanding and adopt interventions that are sensitive to consumer preferences rather than executing blanket recommendations. Positive attitude was found to be a potential contributing factor towards the eating and rearing of BSFL fed chicken. Therefore, it is important to understand the nature and direction of attitudinal influence dimensions and characteristics of farmers for mainstreaming circular

economy interventions. This type of sanitation technology profoundly enhanced the use of human excreta. For instance, the farm respondents who were using improved sanitation facilities (pit latrines and septic tanks) applied were able to treat waste using BSFL technology and generate feeds for poultry, pigs and chicken while farmers with un-improved toilet facilities were not utilizing the technology. Therefore, practitioners and planners champion to create informed demand for improved systems, focusing not only on health but also on improvements in the local environment.

The sensory evaluation component of this study played a pivotal role in understanding the distinct qualities of broiler chickens raised on BSF-based feed compared to conventionally raised chickens. The panelists involved in the sensory evaluation process demonstrated a discerning ability to detect and evaluate sensory attributes, which provided valuable insights into consumer preferences. The sensory evaluation conducted with public university students as consumers revealed a substantial preference for broiler chickens raised on black soldier fly (BSF) based feed.

Students consistently expressed enthusiasm for the taste and overall quality of chicken meat from BSF-fed birds. They cited the richer flavor, tenderness, and juiciness as key factors contributing to their preference were taste Preference, texture and tenderness, Aroma and Smell, Appearance and Colour: While the colour of the chicken meat from BSF-fed birds did not significantly differ from conventionally raised chickens, the overall appearance was noted as more visually appealing due to its juiciness and tenderness and overall Satisfaction.

5.4: Recommendation for the study

The study recommends promotion and education to consumers to encourage the adoption of BSF-based feed in poultry production through educational campaigns to be launched to

inform both consumers and producers about the benefits of this sustainable feeding approach. Highlighting the positive environmental impact and health benefits can help create a greater acceptance of such products. Also, consumer engagement in taste tests, cooking demonstrations, and awareness campaigns to promote the unique qualities and benefits of chicken raised on BSF-based feed.

Market Expansion will encourage poultry producers to diversify their product lines by offering broiler chickens raised on BSF-based feed. Exploring new marketing strategies and distribution channels can help expand the market for such products. Furthermore, offering government support and incentives for poultry producers who transition to BSF-based feed. This could help accelerate the adoption of sustainable practices in the poultry industry.

The study recommends further research on researching and refining BSF-based feed formulas to optimize poultry growth, feed conversion rates, and overall meat quality. This will ensure the continuous improvement of this sustainable approach to poultry production.

5.5: Publication

Kobia, K. P., Riungu, J. N., Mukiri, K. L., & Kiogora, S. D. (2025). Perception and Attitude of Potential Producers and Consumers Towards Eating Broiler Chicken Fed with Black Soldier Fly Larvae in Kenya. IJCSPUB Volume 15, Issue 3 September 2025.

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APPENDICES

Appendix A: Consumers' questionnaire

Phase 1: Sanitation products re- use survey
Name
County
Phone Number
Email
Gender
- Male
- Female

Religion
- Christian
- Muslim
- Hindu
- Other

Please select feeding preferences that best suits you
- Vegetarian
- Vegan
- Non vegetarian

If non vegetarian, list the meat sources that you know
- Pork/bacon
- Chicken
- Beef
- Mutton
- Fish

Tick which types of meat you can eat in above
- Pork/bacon
- Chicken
- Beef
- Mutton
- Fish
- Other:

What informs the type of meat that you can eat?
- Religion
- Culture
- Taste
- Other

Does the feed that an animal consumes influence your acceptability of its product?
- Yes
- No

Black soldier fly larvae convert organic waste e.g. food waste, market waste and or human faeces to rich protein that can be used to formulate chicken feed, dairy feed, pig feeds etc. Is it okay to consume meat produced using these feeds?

Yes
No

If yes, would you consume meat from such meat? *
Yes
No

Phase 2: Sanitation derived products survey

Age bracket
18-25
26-40
41-55
56-70

After using the toilet, we obtain excreta (faeces and urine). These have variously been used as raw materials for production of different items collectively known as sanitation derived products (SDPs). List any SDPs that you are aware of.

Which of the following SDPs can you be comfortable in using?
Compost
Charcoal
Protein (Black soldier fly larvae)
Protein (vermiworm)
Biogas
Urine fertilizer
Struvite
Bio-char
Others

If others in question above, please specify
……...

SDPs can be used to grow crops, rear animals, or as a fuel. For any of the SDP named above, list the products it can be used to grow, rear or process.
…….
.

Which of the following products grown using SDP can you consume/eat?
Fruits
Cereals and grains
Leafy vegetables e.g. spinach, kales cabbage etc.
Rooty vegetables e.g. carrots, potatoes, beet roots etc.

Which of the following reared products from SDPs can you consume/eat?
Eggs
Milk
Poultry
Fish
Beef
Mutton
Pork

Skin/leather (bags, belts, jackets etc.)
Others

In your opinion, food/material produced from SDPs is .....compared to conventional.

Better than
Same as
Poorer/inferior to

If better than, in what ways do you think it is better

……

If better than, which of the following make you consider SDP better

Environmental conservation
Nutrition
Cost effective
Sustainable production
Helps improve sanitation
Other

If inferior to conventional products, what do you think is the reason for it being inferior?

……..

Which of the following reasons make you view it as inferior?

Taboo
Yak factor
Religion
Culture
Health concerns
Taste
Other

List the reasons given above in your order of importance (1-most important, 8-least important)

…….

Some people have issues consuming SDP related products. Do you think they are justified to reject such products?

Yes
No

If yes, please list some of the possible reasons for rejecting such products.

……..

Which of the following sanitation systems best describe what is mostly available at your home?

Container based sanitation
Pit latrine
Flush toilet connected to a pit
Flush toilet connected to a septic tank
Flush toilet connected to a bio-digester (biogas)
Flush toilet connected to a centralized sewer
Composting dry toilets
Bush/open field

After continued use, the excreta fill up in the containment. Which of the following best describes the intervention for the toilet available in your home when full?

Dig a new pit and abandon the old

Empty and reuse the containment/pit

Other

If practice is to dig a new pit and abandon the old one, describe what you do with the content of the old pit/containment

……

If the practice is to empty and reuse the pit, describe what happens to the emptied excreta/faecal sludge from the old pit/containment

……..

Within your locality (area served by your home chief), please select what describes the likelihood of there having incidents of open defecation.

Definite (there is open defecation)

Highly likely

Likely

Not likely

Highly unlikely

None

In Kenya, 45 out of 47 Counties have openly acknowledged that they have open defecation as a problem. Free range chicken and pigs (omnivores) scavenge for feed continuously and consume excreta. Crops in the field can get in contact with excreta too. As well, some people use sewage and waste water to irrigate crops. These crops eventually find their way to the market and grocery stores. Free range cattle consume forage that may have grown on excreta. Additionally, excreta can find its way into water bodies where fish grow consuming it directly or indirectly. Do you normally have issues consuming any animal products based on the possibility of having fed or gotten into contact with excreta?

Yes

No

If yes, please explain the criteria of choosing your meat from the market

……..

Do you normally have issues feeding on plant-based products based on their production practice?

Yes

No

If yes, please explain your criteria of choosing your plant-based products from the market

……
…….

Appendix B: Producers' Interview Guide

Phase 1
Date of Interview:
Name of Moderator:

1. Can you tell me a bit about Black Soldier Fly (BSF) farming and how BSFs can be used?
2. What are the benefits of using BSFs?
    a. For you (e.g. is BSF farming financially sustainable?)
    b. For the environment
3. What concerns do you have about using BSFs?
    a. For you (e.g. is BSF farming financially sustainable?)
    b. For the environment
4. What makes using BSFs easy or difficult?
    a. How easy or difficult is it to access BSFs or the technology necessary to farm BSFs?
    b. How labour intensive is BSF farming?
    c. How costly is BSF farming?
    d. How reliable is BSF farming to manage waste/ create animal feed?
5. How does BSF treatment of organic waste compare to other methods of waste management? (e.g. methods used, cost, safety)
    a. Do you prefer BSF treatment of organic waste or conventional methods of waste management? Why?
    b. What would make using BSF treatment of organic waste easier or more difficult?
6. Can you tell me a bit about what types of organic material (e.g. human manure, animal manure, fruit and vegetable wastes) you would be happy/unhappy to feed to BSF larvae?
    a. Why?
7. How could BSF treatment of organic management be improved?
8. How do insect-based animal feeds (e.g. BSF larvae) compare to conventional animal feeds?
    a. How safe are BSF-based animal feeds for animal consumption?
    b. How safe is it for humans to consume animals who have been fed BSF-based animal feeds?
    c. How safe are BSF-based animal feeds compared to other conventional animal feeds?
    d. How does the cost differ between BSF-based animal feeds and other conventional animal feeds?
    e. Are BSF-based animal feeds as nutritious as other conventional animal feeds? Why?
9. How can BSF-based animal feeds be improved?
10. Have you ever eaten BSFs or BSF larvae? (e.g. directly or integrated into a meal)
    a. Why/ why not?
11. What do other people in your community think about farming BSFs? (i.e. Friends, family, local authority)

a. How does their opinion influence your own decision to use/ not use BSF for waste management?
b. How does their opinion influence your own decision to use/ not use BSF-based animal feeds?
c. How does their opinion influence your own decision to eat/ not eat BSFs?

12. What would help you motivate yourself or others like you to farm BSFs? _____
13. Is there anything else you would like to add? _____

Phase 2
Section 1: Demographics
1. Age:
□ Under 25
□ 25-34
□ 35-44
□ 45-54
□ 55-64
□ 65 and above
2. Religion: _____
3. Gender: _____
□ Male
□ Female
4a) Years of experience in general poultry farming: _____
4b) Years of experience in poultry farming using BSFL feed: _____
Section 2: Current Poultry Farming Practices
5. What type of poultry farming do you primarily engage in? (Select all that apply)
a. Broiler production
b. Layer production
c. Free-range poultry
d. Organic poultry farming
e. Other (please specify) _____
6. How do you currently source protein feed for your broiler chickens? (Select all that apply)
a. Commercial broiler feed from suppliers
b. Home-grown feed
c. Other (please specify) _____
Section 3: Awareness of Sanitation Recycled Meat Production
7. Have you heard of the concept of broiler chicken meat being produced through sanitation recycling processes before this survey?
□ Yes
□ No
If yes, please specify the source of your information: _____
8a. Are you comfortable with the usage of black soldier fly larvae as a protein feed substitute in the production of broiler chicken meat?
□ Yes
□ No
8b. Can you eat this chicken?
□ Yes

□ No
Section 4: Perception of Using Black Soldier Fly Larvae in Broiler Chicken Feed
9. What are/were your initial thoughts or feelings about using black soldier fly larvae as a protein feed substitute in rearing broiler chickens?
□ Interested
□ open minded
□ hesitant/doubtful
10. What potential benefits do you see in using black soldier fly larvae as a protein feed substitute in rearing broiler chickens? (Select all that apply)
□ Reduced feed costs
□ Sustainable protein source
□ Lower environmental impact
□ Improved broiler chicken health and growth
□ Other (please specify) _____
11. What concerns or challenges do you anticipate in using black soldier fly larvae as a protein feed substitute for rearing broiler chickens?
□ Taste
□ Culture
□ Taboo
□ Religion
□ Health concerns
□ Yak factor
Section 5: Willingness to Adopt Black Soldier Fly Larvae in Broiler Chicken Feed
12. Would you consider incorporating black soldier fly larvae as a protein feed substitute for your broiler chickens?
□ Yes
□ No
□ Not sure
13. If yes, what factors would motivate you to make this decision? _____
14. If no or not sure, what are the primary reasons for your hesitation or refusal to use black soldier fly larvae as a protein feed substitute for your broiler chickens? _____
Section 6: Likert Scale Question - Perceptions and Attitudes
Please rate your level of agreement or disagreement with the following statements regarding consuming broiler chicken meat reared with sanitation recycled products, particularly using black soldier fly larvae as a protein feed substitute. Use a scale from 1 to 5, where 1 represents "Strongly Disagree," 3 represents "Neutral," and 5 represents "Strongly Agree."
1. The idea of using black soldier fly larvae as a protein feed substitute in broiler chicken production is appealing.
□ 1 - Strongly Disagree
□ 2 - Disagree
□ 3 - Neutral
□ 4 - Agree
□ 5 - Strongly Agree
2. I believe that using black soldier fly larvae as a protein feed substitute can lead to cost savings in broiler chicken production.
□ 1 - Strongly Disagree

□ 2 - Disagree
□ 3 - Neutral
□ 4 - Agree
□ 5 - Strongly Agree

3. Incorporating black soldier fly larvae as a protein feed substitute aligns with sustainable and eco-friendly farming practices.
□ 1 - Strongly Disagree
□ 2 - Disagree
□ 3 - Neutral
□ 4 - Agree
□ 5 - Strongly Agree

4. I am concerned about potential health risks associated with using black soldier fly larvae as a protein feed substitute in broiler chicken production.
□ 1 - Strongly Disagree
□ 2 - Disagree
□ 3 - Neutral
□ 4 - Agree
□ 5 - Strongly Agree

5. I am willing to invest time and resources in learning more about the benefits of using black soldier fly larvae as a protein feed substitute.
□ 1 - Strongly Disagree
□ 2 - Disagree
□ 3 - Neutral
□ 4 - Agree
□ 5 - Strongly Agree

6. Incorporating black soldier fly larvae as a protein feed substitute can improve the overall environmental sustainability of broiler chicken production.
□ 1 - Strongly Disagree
□ 2 - Disagree
□ 3 - Neutral
□ 4 - Agree
□ 5 - Strongly Agree

7. I am concerned that using black soldier fly larvae as a protein feed substitute might affect the taste and quality of broiler chicken meat.
□ 1 - Strongly Disagree
□ 2 - Disagree
□ 3 - Neutral
□ 4 - Agree
□ 5 - Strongly Agree

8. I would be willing to collaborate with researchers or organizations to explore the implementation of black soldier fly larvae in broiler chicken feed.
□ 1 - Strongly Disagree
□ 2 - Disagree
□ 3 - Neutral
□ 4 – Agree
□ 5 - Strongly Agree

9. Government incentives or subsidies could positively influence my decision to adopt black soldier fly larvae as a protein feed substitute in broiler chicken production.

□ 1 - Strongly Disagree
□ 2 - Disagree
□ 3 - Neutral
□ 4 - Agree
□ 5 - Strongly Agree

10. I believe that consumer demand for sustainable and environmentally friendly products will increase the acceptance of broiler chicken meat reared with black soldier fly larvae as a protein feed substitute.

□ 1 - Strongly Disagree
□ 2 - Disagree
□ 3 - Neutral
□ 4 - Agree
□ 5 - Strongly Agree

11. Please use this space to provide any additional comments or thoughts on the topic of consuming broiler chicken meat reared with sanitation recycled products, particularly using black soldier fly larvae as a protein feed substitute _____

Appendix C: Sensory Evaluation Questionnaire

Triangle test

Assessor: ……. Date: …….

You are provided with three cooked chicken samples; each is labelled with a three-digit code. Two samples are the same and one is different. Taste each sample in the order provided, from left to right, and select the 'odd' sample. Record your result below.

Cleanse your palate with water after each sample. You are permitted to re-taste the samples.

1. COLOUR

Sample	Different sample (Check one)
489	
265	
526	

2. SMELL

Sample	Different sample (Check one)
489	
265	
526	

3. TASTE

Sample	Different sample (Check one)
489	
265	
526	

4. TEXTURE

Sample	Different sample (Check one)
489	
265	
526	

Please comment on how the odd sample is different.

Comments: ……
……

Affective Test

Assessor: ……. Date: …….

You are provided with three cooked chicken samples fed on different feeds. Please indicate on the provided scale your liking of the sample on each of the quality parameters indicated. Cleanse your palate with water after each sample. You are permitted to re-taste the samples.

Colour: Observe the sample. Rank the colour of the sample on the scale below by ticking appropriate box

		CODES		
1	Extremely dark			

2	Very dark			
3	Dark			
4	Slightly dark			
5	Just right			
6	Slightly Light			
7	Light			
8	Very Light			
9	Too light			

Odour: Smell the sample. Rank the smell of the sample on the scale below by ticking appropriate box

		CODES		
1	Dislike extremely			
2	Dislike very much			
3	Dislike moderately			
4	Dislike slightly			
5	Neither like nor dislike			
6	Like slightly			
7	Like moderately			
8	Like very much			
9	Like extremely			

Tenderness: Chew the sample for five times. Rank the tenderness of the sample on the scale below by ticking appropriate box

		CODES		
1	Extremely tough			
2	Very tough			
3	Tough			
4	Slightly tough			
5	Neither tough nor tender			
6	Slightly tender			
7	Tender			
8	Very tender			
9	Extremely tender			

Please comment on your rating below.
Comments……
…

Appendix D: MIRERC Approval

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MERU UNIVERSITY INSTITUTIONAL RESEARCH & ETHICS REVIEW COMMITTEE
(MIRERC)

TO: Kananu Purity Kobia
Through: Dean, School of Engineering and Architecture
FROM: Chairman MIRERC
REF: MU/1/39/28 Vol.2 (41)
SUBJECT: MIRERC clearance and approval of Research
DATE: 17th February 2022

I hereby forward Ethical clearance and approval of your research proposal; *Sensory Evaluation and Customer Acceptability of Fecal Sludge Derived Products in Kenya for* implementation: Note that the implementation of the project should strictly adhere to and follow expected attributes of Justice, Respect, Beneficence and Non-maleficence to the study subjects.

The committee expects to be informed on the progress of the project from time to time and any amendments that may be instituted or incorporated into the proposal during its implementation to be pointed out.

The committee also expects this research project implementer(s) will not at any time risk the study subjects/data in terms of unfair disclosure of information that may come to their knowledge by way of this project or subject the study subjects/data to any bias or consequences whatsoever if or not a study subject withdraws from the project or access to data is denied.

The committee and study subjects will expect to be considered favorably for any benefits that arise from this study. The university would be grateful to act as repository for the data that your project will generate.

The MIRERC committee therefore accords the clearance and approval for this project to be implemented by the investigator(s) during the period specified by the project.

Thank you.
Yours Sincerely,

Prof. Eric Muchiri Ph. D
Chairman, MIRERC
Cc: Director, RDE

M.U.S.T IS ISO 9001:2015 CERTIFIED

Appendix E: Published Journal

IJCSPUB.ORG ISSN : 2250-1770

INTERNATIONAL JOURNAL OF CURRENT SCIENCE (IJCSPUB)

IJCS PUBLICATION (IJCSPUB.ORG) An International Open Access, Peer-reviewed, Refereed Journal

Perception And Attitude Of Potential Producers And Consumers Towards Eating Broiler Chicken Fed With Black Soldier Fly Larvae In Kenya

Kananu Purity Kobia, Joy Nyawira Riungu, Kirimi Lilian Mukiri, Sammy Domenic Kiogora
Meru University of Science and Technology, 60200, Meru, Kenya

Sub Theme: SDG 6. Water, sanitation, and hygiene (WASH) and SDGs

ABSTRACT: The Sustainable Development Goals agenda 2 and 6.2 focus on achievement of zero hunger and attainment of safely managed sanitation for all by 2030 respectively. However, developing countries, Kenya included, seem to be off track in addressing hunger and sanitation issues which continue keeping the population at risk of nutrition and sanitation-related diseases. Although the use of black soldier fly larvae (BSFL) is not only a sustainable and cost-effective faecal waste treatment solution but also a source of proteins and fat for conventional animal feeds, acceptability of the solution remains underexplored. The study explored the acceptability, perceptions and attitudes of potential producers and consumers in Kenya towards this technology for wider adoption. The study used mixed methods research design that enabled collection of quantitative and qualitative data. Producers were involved in focus group discussions (FGDs) and consumers filled semi-structured questionnaires. Qualitative narratives were thematically analysed to identify patterns while quantitative data was analysed using Statistical Package for Social Sciences (SPSS) Version 26.0. Findings showed that 85% of producers did not perceive substituted protein to poultry feed to be a problem. Significant comparisons to other animal protein by the producers suggest that the BSFL broiler chicken was perceived fit for consumption. Results also revealed that 73% of the consumers preferred food produced using BSF compared to the conventional ways of rearing citing reasons like natural and chemical-free production. Additionally, 93% of the consumers stated that it was okay to consume meat produced using the technology and 73% of them reported that the taste of meat was key in informing decisions made relating to eating meat. The study findings suggested that there is a positive attitude towards consuming chicken whose protein feed is substituted with BSFL among potential producers and consumers in Kenya. The results also showed that the use of BSFL as an animal protein source in broiler chicken production has the potential to contribute to safely managed sanitation, sustainable agriculture thus reducing the environmental impact and promoting food security. The study recommends the use of available resources to promote faecal waste management and promote a circular economy in sanitation value chain.

KEYWORDS: BSFL, protein, broiler chicken, consumers, producers, perceptions and attitudes

INTRODUCTION

The Sustainable Development Goals agenda 2 and 6.2 focus on achievement of zero hunger and attainment of safely managed sanitation for all by 2030 respectively (UN, 2015). However, developing countries, Kenya included, appear to be off track in addressing hunger and sanitation issues which continue keeping the population at risk of nutrition and sanitation-related diseases (O'Neill et al., 2018). The rapid increase in the global population coincides with the fundamental challenge of providing improved sanitation options and nutritional diets from a sustainable food system (Béné et al., 2019). A report by World Food Programme (2021) showed that globally, 821 million people live without enough food to maintain a healthy lifestyle. Such inadequate nutritional intake can contribute to development of health conditions such as cardiovascular disease, type 2 diabetes, and obesity (Kahan & Manson, 2017). A report by Food and Agriculture Organization

Appendix F: Plagiarism Report

DrillBit

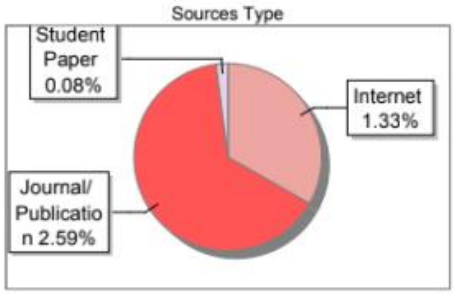
The Report is Generated by DrillBit Plagiarism Detection Software

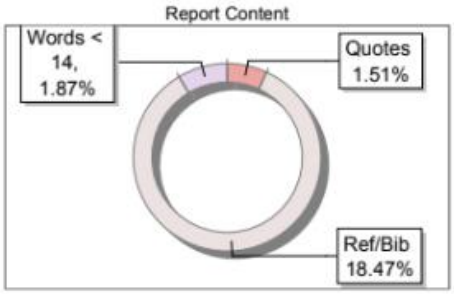
Submission Information

Author Name	KANANU PURITY KOBIA
Title	ASSESSING CONSUMER ACCEPTABILITY, ATTITUDES AND PERCEPTIONS OF FECAL SLUDGE DERIVED PRODUCTS IN KENYA
Paper/Submission ID	2195786
Submitted by	mmusungu@must.ac.ke
Submission Date	2024-08-02 11:25:30
Total Pages, Total Words	125, 28509
Document type	Thesis

Result Information

Similarity **4 %**





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Quotes	Not Excluded
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Database Selection

Language	English
Student Papers	Yes
Journals & publishers	Yes
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Institution Repository	Yes

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