CONTRIBUTIONS OF TERMITES (*Macrotermes subhylanus*) TO IMPROVED PRODUCTIVITY OF INDIGENOUS CHICKEN IN SMALLHOLDER FARMS

CAROLINE MAJUMA

A Thesis Submitted to the Board of Postgraduate Studies in Partial Fulfillment of the Requirements for the Award of Master of Science Degree in Food Security and Sustainable Agriculture of Jaramogi Oginga Odinga University of Science and Technology

JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY

DECLARATION AND APPROVAL

I declare that this thesis is my original work and has not been submitted wholly or in part for any award in this or any other institution of learning.

Signed________________________Date:________20/1/2023_________________

Caroline Majuma A451/4267/2018

Approval

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

Signed ____ ___________Date: 20/1/2023_____________________

Prof. Reuben O. Mosi

School of Agricultural and Food Sciences

Jaramogi Oginga Odinga University of Science and Technology

Signed ____ ______________Date:__20/1/2023____________________

Dr. Kenneth Otieno

Kenya Agricultural and Livestock Research Organization, KALRO

Naivasha Kenya

ACKNOWLEDGEMENT

I wish to thank Almighty God for guiding me through the whole process of proposal inception, development and finally thesis submission. Much appreciation to Jaramogi Oginga Odinga University of Science and Technology (JOOUST) for admitting me to the M.Sc. program and INSEFOODS project for giving me scholarship that has seen me through studies.

I am greatly indebted to my supervisors; Prof. Reuben Oyoo Mosi and Dr. Kenneth Otieno for their guidance, support and advice from proposal inception to thesis write up.

I am also grateful to my colleagues who supported me in various ways in the course of my study and the County Government of Siaya for granting me study leave to pursue my studies.

Finally, my appreciation to my family for their moral support while I pursued my studies.

DEDICATION

To my husband Dr. George Magak and the Children.

ABSTRACT

A growing world population coupled with changing socio-demographics continues to place intense pressure on the world's resources to provide not only more but also diverse food and feed types. Increased demand for animal-based protein resulting from the growing population will have a negative impact on the already stretched environment. More sustainable and alternative sources of protein both for human and animal consumption should be prioritized. Most of the world's population reside in the rural areas and directly depend on the Indigenous Chicken (IC) as a source of both protein and income. There are however concerns on the productivity of IC since they are mostly left to scavenge bringing the challenges of poor nutrition. In an effort to improve the productivity of the IC, farmers have deliberately collected and fed termites to IC. This study outlined the utilisation of *Macrotermes subhylanus*, a wingless termite species as a source of alternative protein to Indigenous chicken for improved food and nutrition security among small holder famers. The aim of the study was to generate knowledge that would promote the utilisation of termites as feed to IC. The specific objectives were to determine the demographic characteristics that influence the use of termites and to determine the nutrient content of *Macrotermes subhylanus*. The study employed a descriptive cross-sectional survey where multistage proportionate and simple random techniques were used to select the 218 respondents. Chi-square tests and logistic regression were used to analyze the collected data using R(version4.0.2) statistical software. *Macrotermes subhylanus* were collected using trapping method, sundried and subjected to proximate and mineral analysis. Proximate analysis was done using the official methods described by AOAC 2000. Calcium was determined spectrophotometrically by using Shimadzu atomic absorption spectrophotometer model AA-6200, while Phosphorus was determined using molybdovanadate reagent and UV visible spectrophotometer. Of the total number of respondents, 142(66.7%) used termites for feeding IC, while 71(33.3 %) did not. Occupation and education level of the respondents had a significant association with termite usage (χ^2 =7.319, p-value = 0.042) and (χ^2 = 15.241, p-value = 0.004) respectively. Dry matter, Moisture, Crude Fiber, Crude Fat, Crude Protein and Ash were 91.5%, 8.5%, 24.25%, 4.55%, 37.7%, and 19.95% respectively. Phosphorus and Calcium levels were 1.85mg/100g and 38.625mg/100g, respectively. It was concluded that *Macrotermes subhylanus* are rich in protein and calcium and could be used as protein supplement for IC.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

IC	-Indigenous Chicken
CP	-Crude Protein
DM	-Dry Matter
MJME	-Mega Joule Metabolizable Energy
KALRO	- Kenya Agricultural and Livestock Research Organization
FAO	– Food and Agriculture Organization
MoALD	- Ministry of Agriculture and Livestock Development
CIDP	-County Integrated Development Plan
LM	-Lower Midland
NPCF	-Nitrogen Protein Conversion Factor
AOAC	-Association of Official Analytical Chemists

CHAPTER ONE: INTRODUCTION

1.1 Background Information

Across the world the consequences of food insecurity present a growing challenge and have been on the increase since 2015 (Saint Ville et al., 2019). With the projected human population of 10 billion people by 2050 (Tomiyama et al., 2020), there is an increased demand for food particularly animal protein found in beef, milk and poultry (Henchion et al., 2017). This increase in population will require an increase in food production of 70% in order to meet the demand for food (Prosekov & Ivanova, 2018). Demand for poultry products has been created by increasing human population, need for high quality protein and increasing levels of income and standard of living.

Small holder farmers in the world's rural areas depend on IC as a source of protein based food and livelihoods (Foluke et al., 2020) Indigenous chickens (IC) are the most widely kept and also widely distributed livestock species in the whole world (Moreki & Chiripasi, 2012). They also play an important role in the provision of both income and food to both rural and urban households. Indigenous chicken in Kenya account for about 76 % of the total poultry population and produce about 55% and 47% of the total meat and eggs respectively (Kingori et al., 2010). Furthermore, they have several advantages, including quick returns to investment, relatively simple management practices and have many market outlets for products. However, IC are characterized by low productivity due to poor nutrition, prevalence of diseases and poor management (Njuguna, 2018). In most cases, they are left to scavenge for insects, food waste, green grass, leafy vegetables and scattered grains (Muthoni, 2021). When available, they were occasionally offered supplemental feed in form of food leftovers. Housing and disease control were not provided regularly. Nutrient intake by IC under free range system is apparently sufficient only for maintenance and low production (Wambui et al., 2018). However, for improved productivity and production, additional inputs are required (Wondmeneh et al., 2016). In Kenya average annual egg production in the traditional free and semi-free range systems is about 40-100 eggs/hen laid in 3-4 clutches each consisting of 12-20 eggs (Wambui et al., 2018). The eggs weigh 25-49 g which is within the range reported for other African countries.

According to Gad et al., (2015) there is potential for increasing production and productivity of IC and this can be achieved through improved housing, disease control, nutrition and genetics. With these improvements, egg production in IC can be increased to about 150 eggs per hen per year (Wambui et al., 2018). In order to improve performance of IC under free range production systems, there is need to generate information on feed available local feed resources to permit evaluation of their nutritional requirement and formulation of appropriate feed ration. Wambui et al. (2018) observed that IC under free systems have a crude protein deficit of 3.2g/bird/day, which retards their growth and productivity. This deficit can be met through supplementation and can increase their growth rate by about 2.7 times.

In order to increase productivity of IC under free range systems, most farmers in the rural areas have for a long time harvested and fed termites to IC (Dao et al. 2020). Termites are considered highly nutritive to both human and animals and are commonly consumed in Sub-Saharan Africa (van Huis, 2017). They are also widely used by smallholder farmers a supplementary feed for poultry in Sub-Saharan Africa (Kenis & Hien, 2014).

Many studies have shown different techniques of harvesting termites. A study by Dao et al., (2020) revealed two methods being used by all the regions under investigations the direct collection from termite mounds and the trapping techniques.

Many studies on the use of termites as feed to poultry have been mostly undertaken in West Africa. In Kenya, most studies have focused on the use of termites as food for humans, leaving out its potential as supplementary feed for poultry. This study was carried out to evaluate the potential of termites as protein supplement to IC for improved food and nutritional security.

1.2. Statement of the Problem

Most world's population reside in the rural areas (Alemayehu et al., 2018).These rural populations are faced with both food and nutrition insecurity and Kenya is no exception. Small scale crop and livestock production especially indigenous chicken play an important role in curbing these insecurities. Indigenous chicken is particularly relied on since it helps in diversifying incomes, provides quality protein, energy, fertilizer and a renewable energy asset in over 80% of the rural households (FAO, 2014). Despite the numerous benefits of the IC, they are still characterized by low growth rate and low egg production consequently causing rural diets to have low protein both quantitatively and qualitatively (Magothe et al., 2012). This affects 90% of those living in the rural areas and who depend on IC for protein source and income. In an effort to increase the productivity of the IC who is most often left to scavenge for food, farmers have devised methods of collecting and feeding termites to the chicken. The use of termites is considered an ancestral practice normally passed from one generation to another (Dao et al., 2020). Termites are highly nutritious insects (Ntukuyoh et al., 2012). In most rural areas of Africa, they are deliberately collected from their mounds to feed poultry. Termites are poised to improve IC production and productivity among small holder farmers due to its accessibility, affordability and high nutritive benefits especially as a source of protein. However, despite this deliberate effort by farmers, the productivity of IC has not improved. This study sought to find out the association between demographic characteristics and usage of termites as well as determine the nutrient content of *Macrotermes subhylanus*, a commonly used termite species in IC feeding.

1.3. Objectives of the Study

1.3.1Overall objective

The study sought to broaden the understanding on the current use, potential and limitations of the use of termites a source of protein to IC as well as determine the nutrient content of *Macrotermes subhylanus* as used in IC feeding.

1.3.2 Specific objectives

1. To determine the demographic characteristics that influence the use of termites as protein supplement for indigenous chicken by smallholder farmers.
2. To evaluate the nutrient content of *Macrotermes subhylanus* as used indigenous chicken feeding

1.3.3 Research Questions

1. What are the demographic characteristics influencing the use of termites as protein supplement for IC by smallholder farmers?
2. What is the nutrient content of *Macrotermes subhylanus*?

1.4 Rationale of the Study

Most of the studies on poultry in Kenya have targeted exotic commercial poultry rearing leaving out the indigenous poultry**.** The few studies targeting poultry are reported from other countries such as Ghana and Ethiopia. There is therefore a paucity of knowledge with regard to the local indigenous poultry. More specifically, very little is documented on the use of termites as a source of protein supplement for IC. Additionally, most studies done in Kenya have been focused on the use of termites as food and not feed. There is need therefore to build a repository of knowledge which would enable extension service providers to assist the farmers improve on the productivity of the IC through the use of locally available feed resources.

1.5. Justification of the Study

Siaya county, with an estimated population of 1,005,816 (528,196 females and 477,620 males), has 33.8% of its population living below the national poverty line. It has few cash crops and most of the people depend on remittances from relatives residing outside the county. For on-farm generation of income, households rely on the sale of livestock particularly indigenous chicken and their eggs. Any investments to improve on the livelihoods of these households must target improving on the use of the existing resources for food security, nutrition and income generation. This study aimed at contributing to the improvement of the productivity of the indigenous chicken as a pro-poor intervention in the effort to improve food security, nutrition and income of the farmers

CHAPTER TWO:
LITERATURE REVIEW

2.1. Use of Termites in Poultry Production

Food insecurity and low incomes coupled with high levels of poverty characterize Kenya's rural areas. Ironically, most world's population reside in the rural areas (Alemayehu et al., 2018). Small scale crop and livestock production particularly IC play a critical role in the nutrition and economic life of these resource poor farmers by providing cheap source of protein and income.

The strength of IC lies in their ability to withstand harsh scavenging conditions, poor nutrition and disease challenges thereby contributing to their low productivity and exploitation. The IC in Kenya are popular in the rural areas and in any human settlement thereby making them to contribute significantly to both food and nutrition security. The IC are however characterized by low weight, late maturity and small egg size consequently causing the rural diets to have low protein (Magothe et al., 2012). For IC to continue being beneficial to rural communities, there is need to supplement the scavenging feed resources already available to IC. Locally available feed resources high in protein like groundnuts, beans, meat and bone scraps, and insects should be used as supplement to compensate the nutrient intake deficit of scavenging chickens and also to reduce input costs (Raphulu et al., 2018). However, for most farmers in the rural areas, insects provide the cheapest alternative non-conventional source of protein to I.C.

The use of termites is considered an ancestral practice normally passed from one generation to another (Dao et al., 2020). Termites play a key role in traditional poultry nutrition since it provides the only source of protein given to chicken and guinea fowls (Sankara et al.,2018). Farmers of IC collect termites to supplement poultry feed. However, IC are still characterized by low egg and meat production pointing to the fact that in spite of this practice there could still be inadequacy in the diets fed given the variations observed in the frequency and quantity of termites used by farmers (Dao et al., 2020).Nevertheless, the fact that termites are already being used by a majority of farmers in Kenya and Africa as a whole opens room for the enhancement of its utilization which is deemed significant in positively influencing and improving IC production and productivity on smallholder livelihoods.

2.1. Contributions of Indigenous Chicken to Food Security

Indigenous chicken refers to chicken that are adapted to harsh environmental conditions that include extensive small-scale village, free range and organic production systems and are also referred to as traditional, scavenging, backyard or family poultry (Pius et al., 2021). IC is deemed important in providing the increasing rural population with high quality protein. Despite requiring low levels of inputs, the IC contributes significantly to poverty alleviation, food and nutrition security and also a source of employment to most people in the rural areas (FAO et al., 2019). IC provide a major income generating activity from the sale of birds and eggs and occasional consumption provides a valuable source of protein (Alemayehu et al., 2018). IC helps diversify incomes and provides quality food, energy, fertilizer and a renewable energy asset in over 80% of the rural households (FAO, 2014). IC provides an excellent entry point to address the problems of food insecurity, malnutrition, low income and poverty as a whole (Alemayehu et al., 2018).

The world's human population is expected to reach the 9 billion mark by 2050 and this increase will lead to increased demand for animal protein (Fróna et al., 2019). IC has the potential to satisfy at least part of this demand through increased productivity. Keeping IC makes a significant contribution to household food security throughout the developing world. Despite these benefits, IC is characterized by low productivity. According to Magothe et al. (2012) some of the factors contributing to low productivity of IC are low genetic potential, feed shortage and disease outbreak.

2.2 Insects as Food

Entomophagy which is the practice of using insects as a part of the human diet, has played an important role in the history of human nutrition in Africa, Asia and Latin America(Madhumita, 2021).

The consumption of insects by human is a practice that has been common throughout the world, especially in the tropics from time immemorial (Malaisse,2019). It is estimated that insects form part of the traditional diets of at least 2 billion people with more than 1 900 species have reportedly been used as food (van Huis, 2017). The utilisation of insects as an alternative, sustainable and secure source of food especially protein has been on the increase in the recent years (Malaisse,2019). Insects are also valuable sources of minerals and vitamins (Kelemu et al., 2015) essential for human development. Insects are considered traditional foods playing a key role in human nutrition (Tang et al., 2019).
Consumption of insects as human food has been promoted for health, environment, economic and social reasons (van Huis, 2020). Several insect species have been and are currently being used by human as food. Some important insects include: grasshoppers,

caterpillars, beetles, bee, wasps, termites as well as a variety of aquatic insects (Tang et al., 2019).

2.3. Insects as Feed

Insects as feed provide an excellent opportunity to reduce food insecurity by reducing land competition between energy and food crops (Eike et al., 2016). Insects are highly suitable for use as livestock feed because they have high nutritional values and are naturally a part of some livestock diets. Naturally, insects form the majority of the world's biodiversity and the tropical ecosystems are dominated by insects in terms of species richness, biomass and provision of ecosystem services (Tiroesele & Moreki, 2012). Insects provide energy, protein, fat, minerals and vitamins to poultry (Józefiak et al., 2016).Cost of feed is known to be the major cost driver in poultry production and the use of insects as alternative source of protein may lower this cost. Insects provide quality protein and other valuable nutrients to most animals and they have formed a part of the natural food source to poultry and fish (Kenis et al., 2014). They are natural food sources for poultry and are considered a fundamental protein source for poultry in the wild (Al-Qazzaz et al., 2016). According to Pomalégni1 et al., (2017), farmers have facilitated access of chicken to insects by letting the chicken out when termites swarm or digging up mounds and letting chicken feed on the termites (Józefiak et al., 2016). Insects contain a good amount of protein which can be as high as 64% with a high balance of essential amino acids. Several insects have been used as poultry feed, these include grasshoppers, houseflies and mealworms (Moula & Detilleux, 2019).

All over the world, several insect species are commercially reared and used as feed for animals. Black soldier fly (*Hermetia illuscens*), the house fly (*Musca domestica*) is commercially reared as animal feed. In the Netherlands, the larvae of the mealworm (*T. molitor*), the lesser mealworm (*A. diaperinus*) and the superworm (*Z. morio*), are reared as feed for reptiles, fish and avian pet (van Huis, 2020).

Varieties of insect species are the natural feed source for fish and poultry and can be exploited and used as animal feed. The amino acids derived from most insects' protein are superior to those from plant supplements in poultry feed formulation (Kelemu et al., 2015).

Wild harvesting and small-scale production of insects are used especially in small and medium scale poultry production in rural areas where farmers can neither afford nor access the commercial feed. Other insects like caterpillars, aphids, wasps, beetles, grasshoppers have been used as complementary food sources for poultry (Ssepuuya et al., 2017)

Termites belong to the order Isoptera. They are small (4 to 15mm long) and vary in colour from white to tan and even black (Engel et al., 2010). They are social insects that live in colonies with a caste system involving the sterile individuals (workers and soldiers) and reproductive individuals (Naushad et al., 2020). They make up 95% of the soil insect biomass in lowland tropical rainforests building their nests in the soil or wood and are present on all the world's continents apart from Antarctica (Naushad et al., 2020). Different data sources show variations in the number of termite species found in the world. The number of termite species in the world is less than 2500 (Engel et al., 2010), approximately 2,500 (van Huis, 2017), more than 2600 (Oguwike et al., 2013) and between 2300-3000 (Culliney, 2013).

Approximately 1,000 termite species are found in Africa, 435 species in Asia and more than 400 species in South America (Engel et al., 2010). Termites have extremely high population densities. The density of the living biomass in the savanna lies between 70–110 kg/ha with the number of termites per square meter reaching a maximum of 15,000 individuals, but population densities between 2,000 and 7,000 termites/m^2 are quite common (Jouquet et al., 2011). Termites play an important role in decomposition processes, nutrient cycling and carbon processing by feeding on detrital matter (Culliney, 2013). However, termites also cause economic problems measured by expenditures used for damage repair and preventive costs (Daniel & Emana, 2014). About 5% of the 1000 known termite species in Africa also attack annual and perennial crops especially in the ASAL areas resulting in significant yield losses (Naushad et al., 2020). Despite their destructive nature, termites have also been used as important non-conventional source of protein to animals especially poultry.

Termites are highly nutritious insects (Ntukuyoh et al., 2012). In most rural areas of Africa, they are collected from their mounds to feed poultry. For example, Kenis & Hien, (2014) found out that throughout West Africa, termites are collected from the wild to feed poultry. Another study revealed that in traditional Ghanaian home in northern Ghana, each farmer has several termitaria that are harvested daily to supplement the daily protein requirements of the chicken. The harvesting is done very early in the morning and afternoon depending on availability and fed to fowls before allowing them to forage on their own (Anankware et al., 2015). This practice not only provides nourishment to the birds but also prevents the birds from roaming far away from home. Pomalégni1 et al., (2017) reported in a study that 72% of the farmers in South-Western Burkina Faso use termites collected from the bush to feed poultry. Different studies have shown variations on the termite species used for poultry feeding. For example, a study on termite use for poultry in Ghana by Hettie et al.,(2019) showed that the most frequently used species in northern Ghana include species of the genera Macrotermes, Odontotermes and Trinervitermes. The use of Cubitermes, Amitermes and Microtermes was mentioned to a lesser extent. Amitermes was cited by more than 50% of the farmers in the Northern region but much less in other regions. Important variations were observed in the genera collected in the different regions. The genus most cited in all the regions is Trinervitermes, with more than 90% of all farmers citing this genus. Perhaps, Trinervitermes is used the most due to the abundance of their mound and the ease of obtaining workers by breaking mounds. This implies that the ease with which the termites are collected or harvested from the mound determine their use as poultry feed (Hettie et al., 2019).

Other studies also show that not all termites' species are appropriate as poultry feed. In Burkina Faso, some species of *cubitermes* are reported to be toxic to chicks but not to guinea fowl and ducks (Dao et al., 2020). In Benin, a study revealed that a humivorus species of the genius *Noditermes* was toxic to both poultry species. Termites are not always available, the quantity available depend on the season, availability of the termite mounds and the termite species. A termite mound can provide about 50kg of termites per year. (Duijn et al., 2018). Several studies have been done on the effect of termite diet on poultry. In West Africa, Burkina Faso Dao et al.,(2020) substituted fish meal with fresh termite of the genius *macrotermes* in chick diets and showed that the daily weight gain was not affected though the feed conversion ratio was significantly higher with termites as compared to fish meal. Similarly, a study in the Democratic Republic of Congo showed that chick feed portions with 12% of termite *Kalotermes flavicollis* resulted in significant results in terms of weight gain and were economically much more profitable than commercial feed (Mutungi et al., 2019).

Macrotermes subhylanus is a wingless termite of the order Isoptera and the family termitidae. They are social insects with a colony consisting typically of workers, soldiers and reproductive individuals (Igwe et al., 2012) and are known to build large termite mounds (Dao et al., 2020) . In many parts of the world, *M.subhylanus* are known to be causing massive destruction to both property and crops. In Africa, they are commonly collected from the wild to feed poultry and are locally known as "*Agoro termites"* in the study area.

Figure 1: *Photo of Macrotermes subhylanusSource: Istockphoto.com*

2.4. Termite Harvesting Techniques

Several techniques have been used by farmers to collect or harvest soldier and worker termites from their mounds. Unlike other insects used as feed and food which can be reared or produced in mass, termites cannot be easily obtained and their rearing is associated with production of methane, an important greenhouse gas. Ntukuyoh et al., (2012) demonstrated that soldier termites can be harvested by cutting some sections of the termiterium with spade causing termites mostly soldiers to come out and brushing them off into plastic containers. Harvesting of soldier termites in Uganda was reported to have been done by using wet grass blades or parts of tree pods or bark, by inserting them into the holes of termite mounds that had been opened with a knife (Shandukani et al., 2018). Harvesting of soldier termites was carried out at any time during the day but more termites were collected in the morning and late afternoon. Soldier termites were collected by inserting grasses or fibre made from trees into the opening of the nest and after a short period withdrawing the grass full of termites (Shandukani et al., 2018).

Farmers have devised several methods of capturing termites from the wild most of which involve use of locally available materials to increase the number of termites available for IC. During a study on the use of termites by farmers as poultry feed in Ghana, the following five termite collection methods were identified (Hettie et al., 2019):

Method one: Whole or part of the mound is removed using an axe or hoe and the base of the mound is dug to loosen it and the whole mound is removed. This method is suitable if the size of the mound is small but is destructive since the same mound can only be re-harvested after it has been rebuilt by the colony.

Method two: A pot or container with organic matter is inverted over trails and small nests. The top soil is removed and the pot filled with organic matter is inverted into the trail and collected after 12 hours. This method does not destroy the trails and can be used for a long time.

Method three: A hole is made in the mound with fresh leaves. Collection is done after a few hours normally around 2-3 hours. Termites that are collected are the ones attracted to feed on the leaves and are collected together with the leaves

Method four: Involves removing part of the mound and waiting for around 5 hours before returning to collect the newly rebuilt part of the mound which is full of termites

Method five: A hole is made in the mound until the farmer reaches the fungus garden (has white colour) and a basket is placed on the hole created, debris collected into a basket and covered with leaves for 24hrs.The basket is collected in the morning and termites fed to birds.

2.5. Nutrient Composition of Termites

Proteins consist of amino acids which are important elements of food and feed nutrition. Amino acids are the building blocks required for the biosynthesis of all proteins through metabolism to ensure proper growth, development and maintenance. Protein content of insects vary depending on feed, species and metamorphosis stage with adults usually having the highest protein content (FAO, 2013). Ntukuyoh et al., (2012) analyzed proximate composition of the queen, soldier and worker termites and showed that the crude protein content of the soldiers was higher than those of the workers and queen. According to CU et al., (2012) the average protein content of termites is 35.34%

(minimum 20.40%, maximum 65.62%) and the average fat content is 32.74% (minimum 21.35%, maximum 46.10%).

Other studies on the proximate composition of termites found out that termites are good sources of fat, proteins, fiber, minerals and vitamins. Termites like other edible insects consist predominantly of proteins (33.19%) and fat (39.74%) (van Huis, 2017b)(Kinyuru et al., 2009). Additionally (FAO, 2013) also showed in a review on the nutrient content of 236 edible insects that termites globally had mean fat and protein values of 32.74 and 35.34% respectively. Studies by (Moreki & Tiroesele, 2012) reported proximate, mineral content and energy composition (% dry matter) of termites in Botswana as follows: Crude protein-(%) 46.3, Crude lipid (%) 30.1, Sodium- 0.20 (g)/100g), Calcium- 0.23(g/100g), Potassium- 0.38 (g/100g), Phosphorus- 0.38 (g/100g), Magnesium- 0.15 (g/100g) , Gross energy- 2457.61 (kJ/100g), Metabolizable Energy- 1843.21 (kJ/100g), and Digestible energy- 3040 (kJ/100g). Termites have notable nutritional value because of their protein, fat (lipid) and essential amino acid. According to FAO, (2013) termites are among the insects with the highest fat content. Sogbesan & Ugwumba, (2008) found out that the winged sexual forms of the African termites (Macrotermes spp) had about 3196 KJ/100g (dry weight basis) caloric value while *M. subhyalinus* had about 2575 KJ/100g (dry weight basis). These findings from the previous investigations show that termites can be used as a protein source in poultry diets. Several authors have cited significant variations on the nutritional composition of termites. These variations have been attributed to the diversity in species, origin, and insect food substrate as well as measuring methods employed (Józefiak et al., 2016). Moisture content varied widely and largely depended on the drying technique used with the mean moisture content of 8.86 g/100g (7.79%) (van Huis, 2017b).

2.6. Indigenous Chicken Nutrient and Mineral Requirements

Nutrient requirement is the minimum nutrient needed by poultry to produce the most desired weight and feed efficiency and also means the lack of any signs of nutritional deficiency (Applegate & Angel, 2014). Proper nutrition is cited as one of the challenges that IC experience under smallholder management system consequently causing the IC to have slow growth rate, late maturity and small egg size (Raphulu et al., 2018).

The birds are dependent on scavenging feed resources which is associated with inadequate nutrition and chickens sometimes are supplemented with maize bran, leftovers and insects depending on the availability. Improvements of chicken production in rural areas can increase the availability of quality protein in the form of meat and eggs to the communities, which will result in alleviation of malnutrition, increased household income and job creation. A few studies have been done to determine the nutrient requirements of indigenous chicken in Africa. Study by Kingori et al., (2010) found out that dietary protein requirement was around 160 g kg^{-1} during 14-21 weeks of age and about 170 g kg^{-1} during a 19 weeks growing period.

Raphulu et al., (2018) gave Venda Indigenous chickens diets that were isonitrogenous with different energy levels and demonstrated that dietary energy levels of 12.42 and 12.66MJMEkg $^{-1}$ DM, in a diet of 180 g CP kg^{-1} DM, supported optimum growth rates at starter (1–7 weeks) and grower phases (8–13 weeks) of Venda chickens, respectively. The same experiment by Raphulu et al., (2018) went ahead to show that a diet containing a CP level of 178 g kg^{-1} DM and energy level of 14MJMEkg^{-1} DM allowed for optimal utilization of absorbed protein and energy for growth of Venda chickens between one day and six weeks old. The dietary protein requirement of indigenous chickens is important in formulating feeds necessary to improve the growth and laying potential of IC. According to an experiment by Kalinda & Tanganyika, (2017) a diet containing 18%CP should be given to IC up to laying because it has an impact on the weight gain of the IC while diets containing 17% CP should be given during laying to increase weight and size of eggs.

Minerals are equally important in the nutrition of IC. For instance, Phosphorous is involved in maintaining body pH, in storage and transfer of energy while Calcium (Ca) is needed for bone and soft tissue development and specifically for the formation of eggshell in laying birds. Magnesium (Mg) is an enzyme cofactor and is important in bone metabolism. Sodium (Na) and Potassium (K) are electrolytes useful in maintaining water balance and blood volume (Adesina, 2012).

2.7 Determination of total nitrogen in foods

For many years, the protein content of foods has been determined from total nitrogen content. The protein content in a food is traditionally estimated by multiplying the total nitrogen content by a NPCF, based on the assumptions that dietary carbohydrates and fats do not contain nitrogen, and that most of the nitrogen in the diet is present as amino acids in proteins. The conversion factor was historically set at 6.25 by assuming that most, if not all, nitrogen in food was derived from protein, and that the nitrogen content of proteins was about 16%. This approach is still an accepted method for calculating the crude protein content of foods and food ingredients (FAO & WHO, 2019).

2.7.1 Kjeldahl method

The Kjeldahl method was originally designed for the brewing industry, for monitoring protein changes in grain during germination and fermentation (FAO & WHO, 2019). First published in 1883, the method has been accepted with modifications as the standard for the determination of nitrogen content. The Kjeldahl method and devices have been significantly modified over the past 100 years, but the basic principles are still valid and include three main steps (Adesina, 2012).

1. Digestion – the decomposition of nitrogen from organic samples by boiling in concentrated sulfuric acid resulting in an ammonium sulfate solution.
2. Distillation – adding excess base to the acid digestion mixture, which converts methane (NH4+) to ammonia (NH3), followed by boiling and condensation of the NH3 gas in a receiving solution.
3. Titration – the amount of ammonia in the receiving solution is quantified

2.7.1 Dumas method

Duma's method is considered a direct method for determination of total nitrogen content. It was developed in 1831 by Dumas, from the observation that nitrogenous compounds heated with alkali give ammonia, which can be determined volumetrically (FAO & WHO, 2019).

Currently, the method consists of combusting a sample of known mass in a high-temperature (range, 800–900 °C) chamber in the presence of oxygen, producing carbon dioxide (CO2), water and nitrogen. The gases are then passed over special columns (e.g., those containing a potassium hydroxide aqueous solution) that absorb CO2 and water. A column containing a thermal conductivity detector at the end is then used to separate the nitrogen from residual CO2 and water, and the remaining nitrogen content is measured.

The measured signal from the thermal conductivity detector for the unknown sample is converted into nitrogen content (FAO & WHO, 2019).

2.8. Conceptual Framework

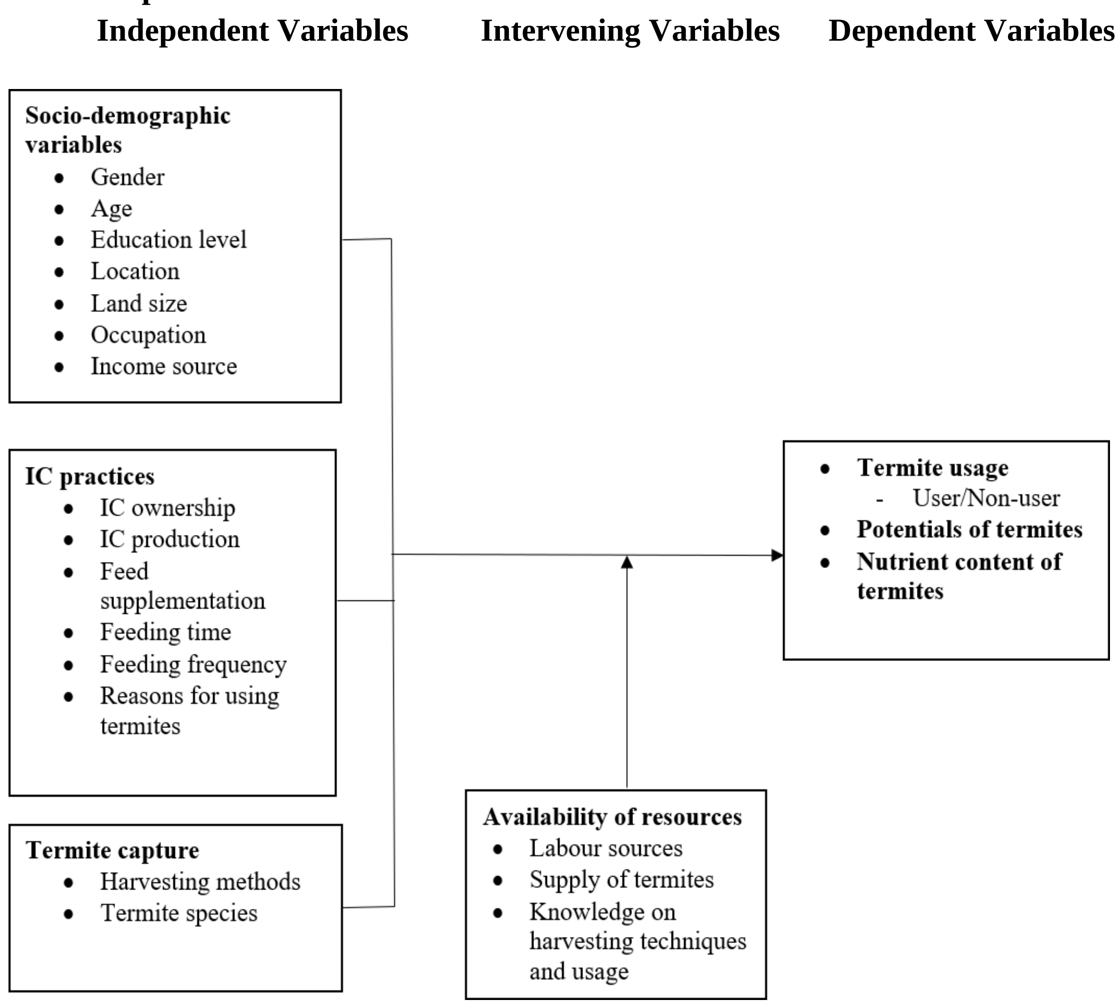

Figure 2: *Conceptual Framework*

The relationship between termite usage, termite availability and termite harvesting methods can be conceptualized at a fairly general level, as depicted in Figure 2. It is expected that termite usage will be dependent on availability of labour for harvesting, availability of termites and knowledge on harvesting and use of termites. Moreover, it is anticipated that termite usage is dependent on socio-demographic variables, IC practices and termite collection.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

This study was done in Siaya county; Alego Usonga sub county. Alego Usonga covers an area of 703.9km square out of which 478sq.km is arable land. The area lies approximately between latitude 0° 26´ South to 0° 18´ North and longitude 33° 58´ and 34° 33´. It has six administrative units namely West Alego, Usonga, Central Alego, Siaya Township, North Alego and South East Alego wards. It borders Gem Sub County to the North, Ugenya and Ugunja to the west and Bondo Sub County to the south. Ecologically the Sub County spreads across agro ecological zones LM_1, LM_2 and LM_3.

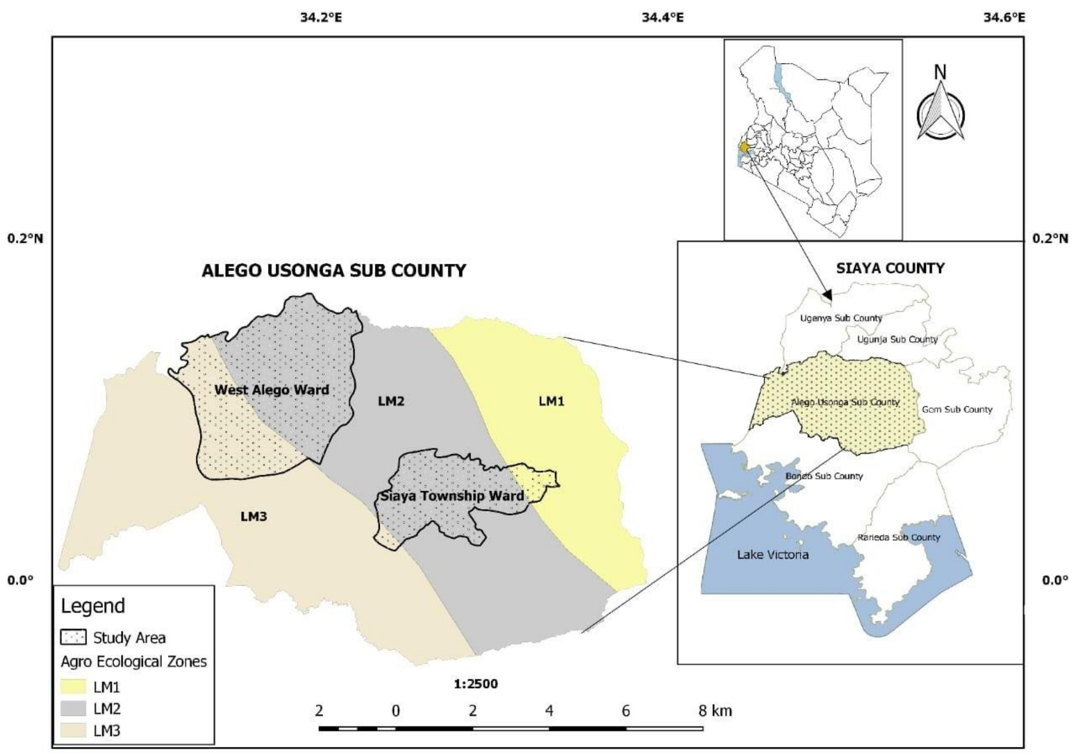

Figure 3: *Map of Alego Usonga Sub-County in Siaya County in Kenya Source: Galaxy Geo consultants, 2023*

3.2. Demographic and Socio-Economics of the Study Area

Alego Usonga has a population of 224,343 persons (GOK,2012). It comprises of 105,906 males and 118,433 females with an annual growth rate of 1.7%. Main food crops are sorghum, beans, cassava, maize and sweet potatoes while livestock reared in the sub county include poultry, cattle, sheep, goats and pigs.

3.3. Biophysical Information

Alego Usonga lies between 1,140 to 1400 meters above sea level. The main soil type is ferrosol with fertility ranging from moderate to low. Most soils are unable to produce without the addition of either organic or inorganic fertilizer. The area has bimodal rainfall pattern with long rain falling between March and July with ranges of between 450mm to 600mm. Short rains take place between September and December and gives between 300mm to 500mm. Temperature ranges between 15^0C and 21^0C with the evaporation rate of 1800-2000mm per year.

3.4. Study Design

Descriptive research design where a survey tool, a cross sectional semi structured questionnaire, was used to achieve objective one. Descriptive research as pointed out by Ebrahim (2018) describes the state of issues as they exist.

For objective 2, a pseudo experiment was done whereby *M.subhylanus*, the most commonly used termites in IC feeding were collected from Township and West Alego wards of Siaya County, Kenya using the trapping method. The termites were dipped in water to remove dust, sundried to immobilize them and divided into two equal parts before being transported to Kenya Agricultural and Livestock Research Organisation

(KALRO) Kakamega, Kenya for proximate and mineral analysis at the animal nutrition laboratory.

3.5 Target Population

Target population as described by (Mugenda and Mugenda, 1999) is a group of objects or items or people from which samples were taken for measurements. The target population was farmers who reside in Alego Usonga Sub County and keep indigenous chicken. The sampling frame was the list of farmers with

IC and who were trained by the department of livestock production on poultry management. This list was obtained from livestock department, Alego Usonga Sub-County.

3.6. Sample Size Determination

According to data obtained from livestock department in Siaya, a total of 479 farmers of IC were trained on poultry management in Township and West Alego wards of Alego Usonga Sub County during the last one year. These farmers were purposively targeted for this study due to the fact that they are knowledgeable on IC nutrition. The sample size was determined using a formula developed by (Israel, 2009):

$$n = \frac{N}{1+Ne^2}$$

Where:
n is the desired sample size
N is the population size
e is the desired level of statistical precision (0.05)
Using this formula, sample size was:

$$n = \frac{479}{1+479(0.05^2)} = 217.975$$

Sample size were 218 farmers in the 2 wards

To determine the number of farmers to be interviewed per ward, the following formula was to apply

$$\text{Number interviewed per ward} = \frac{\text{Number trained in that ward}}{479} * 218$$

Number trained in Township ward was 264 while in West Alego was 215

This gives the number to be interviewed in township ward to 120 and in West Alego ward to be 98 farmers. Simple random sampling was then used to get the respondents.

3.7 Sampling Strategy

Sampling was based on the ownership of IC, having been trained by the department of livestock production on poultry nutrition during the last one year and the willingness to participate on the survey.

3.7 Data Collection

A semi-structured questionnaire was designed and pre-tested in the study villages after which it was then revised and finally administered for objective 1. Data collected included: household characteristics (family size, farmland holding and chicken flock size per household); various productivity of chicken; Chicken management practices including (feeding; feed availability, types and frequency of feeding. Termite usage practices; termite species used (local name); description of termites used; collection or trapping methods; methods of feeding termites to IC. Number of times IC are fed on termites, toxic termite species (local name); description of toxic species; reason for being termed toxic/poisonous; effect on the poultry when fed; variations in the termite species collected.

For objective 2, *M.subhylanus* were collected from both Township and West Alego wards using trapping method. Under this method, the harvester first spots trails of the termites in a field. A pit of 1 foot by 1.5 feet and 6 inches deep is then made, and the pit is cleaned to eliminate safari ants. Dry maize stalks were placed at the bottom of the pit, and the pit is then covered using polythene bag to stop rain water. This was then left overnight. On the following day, soil was poured on top of pit to block the pit and prevent termites from escaping. The termites were then collected together with the plant materials and the soil. The plant materials were discarded and the termites rinsed with water to remove the soil. The termites were then sundried, placed in a plastic container and transported to the lab at KALRO Kakamega for proximate and mineral analysis.

Validity and Reliability

The following measures were taken to ensure validity of the research:

i. Appropriate time was selected for the study;
ii. The most suitable sampling method was used;
iii. The respondents were not, in any way, pressured to select any specific choices among the set of answers provided. There were no leading questions.

The use of a number of interviewers using the same survey instrument would reduce subjectivity and thus ensure reliability. For dichotomous questions (Questions with two possible answers) or Likert scale questions (questions where respondents are asked to rate items on a level of agreement). Cronbach's alpha, α (or coefficient alpha) test was used to measure reliability. In general, an α score of 0.7 and above is usually acceptable. Data entry was done using SPSS (v25) whereas analysis was done using the R version 4.0.2 (RCore Team, 2020) statistical software.

3.8 Data Analysis

Data was analyzed using R version 4.0.2 (RCore Team, 2020) statistical software. Both descriptive and inferential statistics were used to analyze the data. All the tests were done at 95% confidence level.

For objective 1: To determine the demographic characteristics that influence the use of termites as protein supplement for indigenous chicken by smallholder farmers

The interviewed poultry farmers were first described and put into two groups: termite users and non-users. This was later used as the response variable for regression analysis. Descriptive statistic such as frequencies, percentages, means and standard deviations and graphics were used to report the analysis and visualization of the questionnaire data based on whether one is a user or non-user.

Furthermore, Chi-square statistics was used to test for associating between termite usage and the socio-demographic variables such as age, location, gender, education level and occupation. The Chi-square is given by the formula:

$$\chi^2 = \frac{\sum_{i=1}^{n}(O_i - E_i)^2}{E_i} \qquad (1)$$

Where;

χ^2 – is the Chi-square statistics tested at 95% confidence level

O_i – the observed values (frequencies) sampled from i = 1, …, n

E_i – the expected values (frequencies)

Moreover, a binary logistic regression was fitted to assess the significant effect socio-demographic variables on termite usage. The model was picked based on the nature of the response (termite user/non-user). The model specification was as follows:

$$Y = \exp\left(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon_{ij}\right) \quad (2)$$

Where;

Y – is the response variable, termite usage (User/Non-user)

β_0 – is the intercept

β_i – the estimates of the regression parameters (slopes) for i = 1, …, n

$X_{i's}$ – are the independent variables, sociodemographic variables (ward, gender, age, occupation, education level and farm size in acres) for i = 1, …, n.

For objective 2: To evaluate the nutrient content of the most commonly collected termite species in indigenous chicken feeding

Macrotermes subhylanus were collected using trapping method in the two areas of study. The termites were dipped in water to remove soil, sundried and transported in a plastic container to the lab for the analysis.

3.9 Mineral Analysis

Sample preparation for the mineral analysis

The samples were properly mixed and homogenized before weighing 1g into a crucible (Foss- Borosilicate 3.3, Por. 2). Thereafter, the samples were dried in an air forced oven (MRC- Scientific instruments, Model PF120, Serial Number 21-302357) for 1 hour at 105℃. The samples in the crucible were then taken to a pre-heated muffle furnace (Barnstead Thermolyne-type 48000 furnace, Model No. F48010) and heated at 550℃ for 3 hours until all the organic materials were ashes. The residues were visually viewed to ensure they are free from carbonaceous particles. The crucibles were taken to a desiccator and allowed to cool to room temperature. Upon cooling down, the ash was transferred into a 250 ml volumetric flask and 1 ml of HNO_3 was added to dissolve it. The volume was then made up to 250 ml mark using distilled water. The ash solution was then filtered using chm filter papers (F1001 grade, size 125mm).

3.10 Calcium Analysis

Step 1: Preparation of standard stock solutions

Calcium carbonate ($CaCO_3$) dried overnight at 200℃ and then 1.249g was weighed and dissolved in 1000ml distilled water to give a concentrated standard stock solution of 500mg Ca/L. A diluted standard stock solution containing 20mg Ca/L was made by adding 40ml concentrated stock solution to 1000ml volumetric flask and toped up with distilled water to 1000ml mark (Chromý et al., 2015).

Step 2: Preparation of reagent (1% Lanthanum chloride stock solution)

A weight, 26.74g of Lanthanum chloride ($LaCl_3$) was weighed into a beaker, thereafter, 25ml of HNO_3 was slowly added. The volume was then topped up to 1000ml mark using distilled water.

Step 3: Preparation of standards

Volumes of 0, 2.5, 5, 7.5, 10, 12.5, and 15ml of diluted standard stock solution were pipetted into a series of 50ml volumetric flasks. A 5ml Lanthanum reagent was then added and mixed. Thereafter the volume was toped up to 50ml mark by distilled water. This total volume gave 0-6 µg/ml of Ca in 0.1% La.

Step 4: Preparation of sample solution for Calcium determination

A 5ml volume of sample solution was pipetted into a 50ml volumetric flask. Thereafter, 5ml of Lanthanum reagent was added to the sample solution and mixed. The volume was then topped up to the 50ml mark by distilled water.

Step 5: Calcium determination

Shimadzu, Atomic Absorption Spectrophotometer (Model, AA-6200) was allowed to warm up for 10 minutes with flame and source lamp lit prior to sample analysis. The wavelength was set at 422nm and the lamp current at 10 mA for Calcium determination. The absorbance was adjusted to 0 with 0 µg/ml standard. Thereafter, the test samples and the standards were run under the same conditions. The concentrations of Calcium in the samples were determined in µg/ml against 4 or 5 standard solutions. The mineral content present in the sample was calculated in mg/100g as follows;

$$\text{Minerals in mg/100g} = (C \times D) \div W \qquad (3)$$

Where:

C = µg/ml of the mineral in the assay solution
W = gram weight of the sample

D = dilution factor × factor for transforming to mg/100g

⇒ $[(250 \times 50)] \div 10 \times (100 \div 1000) = 125$

3.10.1 Phosphorus Analysis

Step 1: Preparation of standard stock solutions

Ammonium dihydrogen phosphate (NH_4) H_2PO_4 was dried overnight at 110℃ and then 1.114g was weighed and dissolved in 1000ml distilled water to give a concentrated standard stock solution of 300mg P/L. A diluted standard stock solution containing 12mg P/L was made by adding 40ml concentrated stock solution to 1000ml volumetric flask and toped up with distilled water to 1000ml mark.

Step 2: Preparation of reagent (Molybdovanadate solution)

While stirring, molybdate solution was gradually added to vanadate solution to give

Molybdovanadate reagent. A 1.5g mass of ammonium metavanadate was weighed into a beaker, thereafter, 690ml of hot distilled water added to it, 300ml HNO_3 was then added and allowed to cool to 20℃ and then distilled water was added up to the 1000ml mark.

Step 3: Preparation of Vanadate solution

A 60g mass of ammonium molybdate tetrahydrate was weighed into a beaker and 900ml hot distilled water added to it and allowed to cool to 20℃ and then distilled water was added up to 1000ml mark.

Step 4: Preparation of phosphorous standards

Volumes of 0, 5, 10, 15, 20, 25, 30, and 35 ml of diluted standard stock solution were pipetted into a series of 50ml volumetric flasks. Furthermore, 10ml Molybdovanadate reagent was then added and mixed. Thereafter the volume was toped up to 50ml mark by distilled water.

Step 5: Preparation of sample solution for phosphorous determination

A 10ml volume of sample solution was pipetted into a 50ml volumetric flask. Thereafter, 10ml of Molybdovanadate reagent was added to the sample solution and mixed. The volume was then topped up to the 50ml mark by distilled water.

Step 6: Phosphorous determination

The UV visible spectrophotometer (Model UV mini-1240 Shimadzu) was preheated for 1 hour prior to sample analysis. The wavelength was set at 400nm and the absorbance was adjusted 0 with 0 µg/ml standard. Thereafter, the test samples and the standards were run under the same conditions. The concentration of phosphorous in the samples was determined in µg/ml against 4 or 5 standard solutions.

The mineral content present in the sample was calculated in mg/100g as follows;

Minerals in mg/100g = (C×D) ÷ W (4)

Where:

C = µg/ml of the mineral in the assay solution

W = gram weight of the sample

D = dilution factor × factor for transforming to mg/100g

➡ [(250 ×50)] ÷ 10 × (100 ÷ 1000) = 125

3.11 Proximate Analysis

Proximate analysis was done using the official methods described by AOAC 2000.

3.11.1 Determination of Crude Protein

Nitrogen was determined using standard method of Kjeldahl (Chromý et al., 2015). The sample was digested using sulphuric acid in the presence of a catalyst to convert the sample nitrogen to ammonium sulphate. The acid solution was made alkaline with sodium hydroxide solution. The ammonia was distilled and collected in an excess of boric acid solution, followed by titration with sulphuric acid solution. For determination of crude protein, nitrogen was multiplied by a factor of 6.25 (Chromý et al., 2015).

Formula for calculation

$$\%Nitrogen = \frac{1.5V*N}{W} \quad (5)$$

Where V= Acid used in titration (ml)

N=Normality of the standard acid

W= Weight of sample

For CP determination, % N was multiplied by 6.25 (Protein factor for all feeds, forages and mixed feeds)

3.11.2 Determination of Dry Matter

Dry matter was determined gravimetrically as the residue remaining after drying at 103^0C in a ventilated oven.

Percent Total Dry Matter (Total DM):

$$\% \, Total \, DM = \frac{(Dry \, weight \, of \, Sample \, and \, Dish - Tare \, Weight \, of \, Dish)}{(Initial \, Weight \, of \, Sample \, and \, Dish - Tare \, Weight \, of \, Dish)} \times 100 \qquad (6)$$

3.11.3 Determination of Moisture Content

% Total moisture content = 100 - % total DM (7)

3.11.4. Determination of Crude Ash

Crude ash was determined gravimetrically as the residue after incineration at 550^0C

Weight of ash = (weight of crucible and ash) – weight of crucible

$$\% \, Ash = \frac{Weight \, of \, Crucible \, and \, Ash}{Original \, Sample \, Weight} \times 100 \qquad (8)$$

3.11.5 Determination of crude fat

Crude fat/extract-Fat was extracted from the sample using petroleum ether

CHAPTER FOUR:

RESULTS OF THE ANALYSIS

4.1 Descriptive Statistics

4.1.1Response Rate

A total of 218 indigenous chicken farmers were interviewed. The main subject of interest was, if a respondent is a termite user or non-user. Of the 218 respondents, 213 (97.7%) responded to the question on termite usage whereas 5 (2.3%) didn't respond to this question. The response rate was thus 97.7% and hence the validity of the data.

4.1.2 Socio-Demographic Characteristics

There were more females 141 (64.7%) than males 77 (35.3%). Half of the participants had primary level education 109(50%) and 77(33.3%) had secondary education. Majority of the participants depended on agricultural production of crops as main source of income 180(82.6%) and livestock production was mentioned by 91(41.7%) as the other source of income. The majority of the ownership of chicken was women, 48.6%, followed by men at 23.9% whereas the joint ownership took a share of 25.5%. Majority of the respondent were less than 36 years at 83 (38.1%), followed by age 36 – 50 years and above 50 years at 75 (34.4%) and 60 (27.5%) respectively. For further details, see Table 4.1.

Table 1: *Socio-demographic characteristics*

SOCIO DEMOGRAPHICS	FREQUENCY (%)
Gender	**N (%)**
Male	77(35.3)
Female	141(64.7)
Level of education	
None	17(7.8)
Primary	109(50)
Secondary	77(33.3)
College	12(5.5)
University	3(1.4)
Main source of income	
Regular employment	9(4.1)
Agric crops	180(82.6)
Agric livestock	12(5.5)
Casual	4(1.8)
Others	13(6.0)
Other sources of income	
Regular employment	1(0.5)
Agric crops	59(27.1)
Agric livestock	91(41.7)
Casual	55(25.2)
Others	12(5.5)
Ownership of IC	
Wife	106(48.6)
Husband	52(23.9)
All	55(25.5)
Age of respondent	
Less than 36 years	83(38.1)
36-50 years	75(34.4)
Above 50 years	60(27.5)

4.1.2 Extent of Use of Termites as Feed to I.C

Of the total number of respondents, 142(66.7%) were categorized as users while 71(33.3 %) as non-users. Out of the 142 users of termites, 72.7% cited main reason for using termites as a sourceof protein while 24.8% give termites because it is easily accessible. Of the farmers who utilize termites, 83.1% give them to all ages of the IC and only 10.5% discriminate onage and feed the chicks only. Majority of the farmers fed IC once per day in the mid- morning just before scavenging (60.1%) while 25.7% give termites two times a day-both morning and evening, see Table 2.

Table 2: *Farmer practices associated with termite feeding*

Variable	Percentage response (%)
Main reason for using termites	
Source of protein	72.7
Easily accessible	24.8
Easy digestion	1.7
Palatable	0.8
Age of chicken fed on termites	
All ages	83.1
Chicks only	10.5
Adults only	5.9
No of times feeding in a day	
Once	60.1
Twice	31.9
Thrice	8.0
Feeding time	
Mid-morning	60.1
Mid-day	8.8
Evening	5.4
Both morning and evening	25.7

4.1.3 Identified Methods of Termite Harvesting

Five harvesting methods were used by the respondents. Out of 148, a total of 70 (47.3 %) farmers cited method 3 followed by 50 (33.8%) who indicated that they use method 1. Methods 2, 4, and 5 were cited by 16(10.8%), 9(6.1%) and 3 (2.0%) respectively, Figure 1. The identified harvesting methods are defined as follows:

Method one: Whole or part of the mound is removed using an axe or hoe. This method typically involves destroying the mound.

Method two: A pot or container with organic matter is inverted over trails and small nests. Not much used because the pots are likely to be damaged by passerby especially children.

Method three: In this method, the farmer first goes out to scout for the presence of the termites normally starting from around 3metres away from the mound. Once the farmer is certain of the likelihood of the termites, normally the *M.subhylanus*, a hole of 1 foot by 1.5 feet and 6 inches deep is made; the hole is cleaned to eliminate safari ants. Dry maize stalks or chewed sugarcane stalks are placed at the bottom of the hole, dry or wet cow dung or thatching grass are also used depending on availability. The hole is then covered using polythene bag to stop rain water. Once this is set, it is left overnight and the termites are attracted to feed o these materials are the ones harvested the following day in the morning. This was the predominant method used by the harvesters.

Method four: Involves removing part of the mound and waiting for around 5 hours before returning to collect the newly rebuilt part of the mound which is full of termites

Method five: A hole is made in the mound until the farmer reaches the fungus garden (has white colour) and a basket is placed on the hole created, debris collected into a basket and covered with leaves for 24hrs)

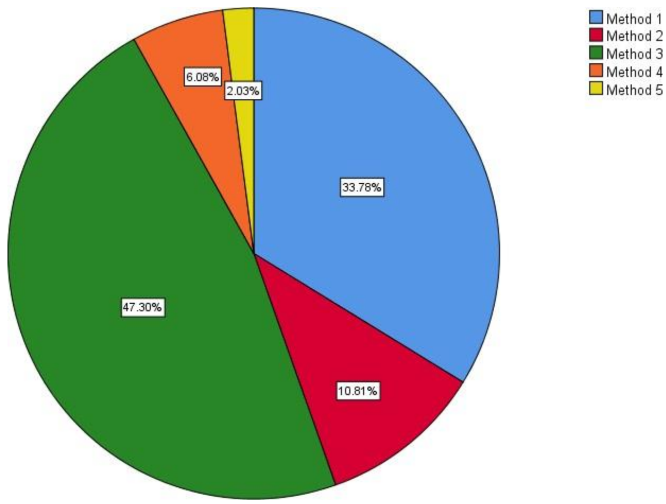

Figure 4: *Proportional distribution of harvesting methods*

4.2. Chi Square Test

4.2.1. Assessing the Associations between Termite Usage and Socio-Demographic Variables

The tests for association indicated that location (ward), gender and age had no significant association with termite usage as signified by insignificant p-values (χ^2=3.402, p=0.065; χ^2=1.023, p=0.312 and χ^2=3.03, p=0.219 respectively). On the other hand, occupation and the education level of the respondent had a significant association with termite usage (χ^2=7.319, p=0. 042 and χ^2=15.241, p=0.004 respectively), Table 3.

Table 3: *Association between termite usage and socio-demographic variables*

	Termite Usage						
	No		**Yes**				
	N	**%**	**N**	**%**	**Totals**	**χ^2 (df)**	**P-value**
Ward							
Township	44	62.0	69	48.6	113		
West Alego	27	38.0	73	51.4	100	3.402(1)	0.065
Gender							
Male	22	31.0	54	38.0	76		
Female	49	69.0	88	62.0	137	1.023 (1)	0.312
Age of the farmer							
Less than 36 years	22	31.0	61	43.0	83		
36 - 50 years	26	36.6	46	32.4	72	3.03 (2)	0.219
Above 50 years	23	32.4	35	24.6	58		
Occupation							
Farmer	69	97.2	121	85.2	190		
Teacher	0	0.0	1	0.7	1		
Business Person	2	2.8	15	10.6	17	**7.319 (3)**	**0. 042***
Employed	0	0.0	5	3.5	5		
Education level							
None	11	15.5	6	4.2	17		
Primary	39	54.9	66	46.5	105		
Secondary	17	23.9	60	42.3	77	**15.241**	**0.004***
College	2	2.8	9	6.3	11	**(4)**	
University	2	2.8	1	0.7	3		

*** Means significant at 5% level and thus there exists an association**

4.2.2. Assessing the Associations between Harvesting Methods and Socio-Demographic Variables

The tests on association between harvesting methods and socio-demographic variables indicate that gender (χ^2 =4.005, p=0.405), education level (χ^2=18.669, p=0.286) and age of the respondent (χ^2=9.392, p=0.310) had no significant association with harvesting methods. However, the tests reveal a significant association between the location (ward)and the harvesting method of the termites (χ^2=11.812, p=0.019). For detailed information,see Table 4.

Table 4: *Association between harvesting methods and socio- demographic factors*

	Harvesting method of termites												
	Method1		**Method2**		**Method3**		**Method4**		**Method5**				
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**Totals**		
												χ^2(df)	**P-Value**
Ward													
Township	17	34	8	50.0	39	55.7	7	77.8	3	100.0	74	**11.812 (4)**	**0.019***
West Alego	33	66	8	50.0	31	44.3	2	22.2	0	0.0	74		
Gender													
Male	18	36	6	37.5	28	40	1	11.1	2	66.7	55	4.005 (4)	0.405
Female	32	64	10	62.5	42	60	8	88.9	1	33.3	93		
Education level													
None	0	0	1	6.3	4	5.7	1	11.1	0	0.0	6		
Primary	24	48	5	31.3	33	47.1	7	77.8	1	33.3	70		
Secondary	25	50	9	56.3	25	35.7	1	11.1	1	33.3	61	18.669 (16)	0.286
College	1	2	1	6.3	7	10.0	0	0.0	1	33.3	10		
University	0	0	0	0.0	1	1.4	0	0.0	0	0.0	1		
Age of the farmer													
< 36 years	22	44	7 (43.8)		32 (45.7)		0 (0)		2	66.7	63		
36 - 50 years	17	34	4 (25)		23 (32.9)		5 (55.6)		0	0.0	49	9.392 (8)	0.310
> 50 years	11	22	5 (31.3)		15 (21.4)		4 (44.4)		1	33.3	36		

*** Means significant at 5% and thus there exists an association**

4.2.3. Assessing the Association between Harvesting Method and the Type of Termite Harvested

Various termite species were harvested. *Macrotermes subhylanus* appears to be the highly harvested species by the respondents, 91 (65.9%), followed by *Macrotermes bellicosus* and *Amitermes spp* that were indifferent at 16 (11.6%). The least harvested were *Amitermes spp* and *Pseudacanthotermes spp* at 8% and 4% respectively. Method 3 appears to be the most preferred harvesting method followed by Method 1 and Method 2 respectively. However, the Chi-squares test indicates that there exists no statistical association between harvesting method and the type of termite species harvested, see Table 5.

Table 5: *Test of association between harvesting method and the type of termite harvested*

	Method 1		**Method 2**		**Method 3**		**Method 4**		**Method 5**				
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**Totals**	**χ^2 (df)**	**P-value**
Termite species harvested													
Macrotermes subhylanus	30	66.7	10	62.5	45	68.2	5	62.5	1	33.3	91		
Amitermes spp	3	6.7	0	0.0	5	7.6	3	37.5	0	0.0	11		
Macrotermes bellicosus	6	13.3	1	6.3	8	12.1	0	0.0	1	33.3	16		
Trinervitermis spp	5	11.1	5	31.3	5	7.6	0	0.0	1	33.3	16	23.515 (16)	0.101
Pseudacanthotermes spp	1	2.2	0	0.0	3	4.5	0	0.0	0	0.0	4		
Total	**45**		**16**		**66**		**8**		**3**		**138**		

4.3. Binary Logistic Regression

A binary logistic regression was also fitted to assess how socio-demographic variables affect termite usage. Termite usage (user/non-user) was taken as the response variable whereas location (ward), age, occupation, education level and land size in acres were used as the independent/predictor variables. The output clearly indicates that location, gender, age and land size do not affect utilization of termite as indicated by the insignificant p-values (p = 0.267, p = 0.356, p = 0.426 and p = 0.102

respectively). On the other hand, occupation and level of education affect the utilization of termites as indicated by the p-values less than 0.05 (p = 0.027 and p = 0.018 respectively), Table 6.

Table 6: *Summary of results on the logistic regression parameters*

	B	Std. Error	Wald	DF	P-value	Exp(B)
Ward	-.374	.337	1.233	1	0.267	0.688
Age	-.189	.205	.853	1	0.356	0.827
Gender	-.250	.314	.633	1	0.426	0.779
Occupation	1.020	.461	4.898	1	0.027*	2.774
Education level	.517	.219	5.603	1	0.018*	1.678
Land size in acres	-.155	.095	2.675	1	0.102	0.856
Constant	-.950	.564	2.839	1	0.092	0.387

*** Means significant at 5% level of significance**

4.3. Limitations of Use of Termites as Reported by Respondents

Out of 137 respondents, 57(41.6%) cited termite harvesting and feeding to IC as labour intensive. On the other hand, 48(27.7%) feel termite supply is scarce especially duringdry season whereas 27(19.7%) think that lack of knowledge on appropriate harvesting techniques is a challenge for using termites. Toxicity of some termite species to chicks is cited by 13(9.5%) of the respondents as a limitation to its use, Table 7.

Table 7: *Limitations of use of termites as reported by the respondents*

Limitation	**Frequency (N)**	**Percent (%)**
Labour intensive	57	41.6
Termite supply is scarce/seasonal	48	27.7
Lack of knowledge on appropriate harvesting techniques	27	19.7
Toxic to chicks	13	9.5
Termites are destructive to properties	2	1.5
Total	**137**	**100**

4.4. Opportunities for Improvements as Reported by the Respondents.

Capacity building on the various aspects of termite usage is mentioned by many respondents. Training on the exact nutritive value of termites and on which termite among the termite species are more nutritious to IC was cited by 65(43%) of the 151 respondents. Training on sustainable and appropriate harvesting technique 43(28.5%) that can result in more harvest. Sustainable mound management 13(8.7%) and general knowledge of termites as feed (right age of IC to feed termites, identification of the toxic termites) was cited by 30(19.8%) of the respondents, Table 8.

Table 8: *Opportunities for improvement*

Potentials	N	%
Training on nutritive value of termites	65	43.0
Knowledge on appropriate harvesting method	43	28.5
General knowledge of termites as feed to IC	30	19.8
Sustainable mound management	13	8.7

4.5. Results for Proximate and Mineral Analysis

Table 9 shows the results for proximate and mineral analysis of ***M.subhylanus*** the commonly used termite in IC feeding among smallholder farmers in the study area. The results indicated that the insect is rich in moisture, crude fibre and crude protein but low in crude fat. Generally, West Alego performs well nearly in all the tests except for Moisture and CP content where Township surpasses it. On the other hand, mineral analysis indicates that ***M.subhylanus*** are high in calcium but low in phosphorus.

Table 9: *The average results of duplicates from chemical analysis of M.subhylanus)*

PARAMETER-%	***M.subhylanus* Township**	***M.subhylanus* West Alego**
Dry matter	90.5	92.5
Moisture	9.5	7.5
Crude fibre	24	24.5
Crude Fat	4.5	4.6
Crude Protein	39.4	36.1
Crude Ash	17.8	22.1
Mineral (mg/100g)	***M.subhylanus* Township**	***M.subhylanus* -West Alego**
Calcium	33.625	43.625
Phosphorus	1.74	1.95

A comparison between the two locations was then done using one way analysis of variance to show if there exists a significant difference in chemical properties of ***M.subhylanus***. The least significant difference (lsd) test was done as a mean separation procedure to indicate where the exact difference lies. This produced letters where by different letters signified significant difference between the two locations while same letters implied the contrary. All the tests were done at 95% confidence level.

Table 10: *Summary results of chemical analysis across the two locations*

	Ash	Dry Matter	Moisture	Crude Fibre	Crude Fat	Crude Protein	Phosphorus	Calcium
Location	**Mean± SE**	**Mean± SE**	**Mean± SE**	**Mean± SE**	**Mean± SE**	**Mean± SE**	**Mean± SE**	**Mean± SE**
Township	17.8±0.3^{a}	90.5±0^{a}	9.5±0^{a}	24.0±0^{a}	4.5±0.42^{a}	39.4±0.2^{a}	1.74±0^{a}	33.6±0.7^{a}
West Alego	22.1±0.1^{b}	92.5±0^{b}	7.5±0^{b}	24.5±0.7^{a}	4.6±0^{a}	36.1±0.3^{b}	1.95±0^{b}	43.6±0.5^{b}
P-value	0.00269*	<2e-16*	<2e-16*	0.423	0.771	0.00587*	0.00895*	0.00389*

Note: *implies significance at 5%. Different lsd (least significance difference test) letters, implies difference in means

Comparing the two regions, Township and West Alego, there was a significant difference in the chemical components' ash, dry matter, moisture, crude protein, phosphorus and calcium. However, the termite chemical composition, crude fibre and crude fat did not vary significantly across the two regions.

High preference would go for termites from West Alego if the interest was Ash, Dry matter, Phosphorus and Calcium since West Alego produced high averages for these components. Moreover, if the interest was in Moisture and Crude protein content, then Township is an ideal location. For interest on both crude fibre and crude fat, the two locations are indifferent. These can be outsourced form any location of preference.

CHAPTER FIVE

DISSCUSSIONS

5.1 Introduction

This chapter discusses the findings as per the objectives and conclusions based on the findings of the study.

5.2. Socio-Demographic Characteristics

Main source of income for the majority of the respondents were crops production indicating that farmers in the study area mainly depend on agricultural production as their main source of livelihoods. IC was mostly owned and managed by the women at 106(48.6%) followed by joint ownership at 55(25.5%). Youths with ages between 18-36 years were more at 83(38.1%) followed by respondents with ages of between 36-50 years 75(34.4%). This trend shows increased youth participation in agriculture.

The total number of IC kept has a maximum of 93, a minimum of 1 and an average of 24.47 indigenous chickens with a standard deviation of 17.724. Chicks were more compared to other ages of IC. The minimum land acreage per farmer is 0.25 and a maximum of 25. The average land acreage per farmer is 1.23 acres.

5.3. Extent of Use of Termites as Feed to IC

Findings of this study indicate that 66.7% of the respondents' harvest and give termites to IC. This translates to 142 respondents who harvest and feed termites to IC. A study by Sankara et al., (2020) showed that 78% of the farmers interviewed in Burkina Faso used termites as feed to poultry.. Source of protein was cited by 72.7% of these users as the main reason for giving termites. This finding agrees with Dao et al., (2020) who indicated that termites may be the only source of proteins available to IC. The study reveals that majority of the respondents are aware of the need to include protein to IC diet. Other 24.8% of the users indicated that their main reason for harvesting and feeding termites to IC is because they are easily available and liked by the IC. This category however did not associate termite feeding with any nutritional benefit to the IC.

Additionally, of the 142 users of termites, 83.1% mentioned that they harvest and feed termites collectively to all IC. This implies that once the termites are harvested, the whole harvest is poured on the ground and all IC allowed accessing the harvest. This finding contradicts with the finding by (Kenis & Hien, 2014) which indicated that most farmers in West Africa mainly collect and feed termites mostly to chicks.

The findings also show variations in frequency in termite usage. 60.1% of the farmers give termites once per day in the mid-morning before scavenging. However, a study by Kenis & Hien, (2014)showed that IC are fed thrice per day in order to provide the required protein and to prevent the IC from wandering far away from the homes hence preventing predation. Feeding IC once per day may not provide the required protein to promote growth of the IC.

Findings reveal that there is no significant relationship between gender, age and location and the utilization of termites. However, there is a significant relationship between occupation and the use of termites. Occupation influences the scale of production hence the small scale farmers are more likely to feed termites to IC. Dao et al., (2020) indicated in his study that harvesting and utilization of termites become a challenge with a big flock size. Education level also had an association with use of termites. Education on the other hand influences level of income; therefore, respondents with higher education levels would not consider using termites to feed IC.

A binary logistics regression outputs also affirmed that education level and occupation had a significant relationship with the utilization of termites as protein source to IC.

5.4. Harvesting Methods

Five methods of harvesting termites were mentioned by the respondents. This finding was in agreement with the findings by Hettie et al., (2019) .The findings show that majority (47.3%) of the respondents prefer method three. In this method**,** a hole is made in the mound or near a mound with fresh leaves and collection is done after a few hours normally around 2-3 hours. Farmers who use this method usually put these traps late in the evening and only go back in the morning to collect the harvest. Termites collected here are the ones attracted to feed on the leaves and are collected together with the leaves and the soil particles. This method allows the respondents' time to perform other activities as they wait for the termites to collect. It may also be preferred since it is sustainable and does not result into damage of the mounds. Additionally, method 3 could also be common because it may be user and gender friendly and also because it is less labour intensive as compared to the others. Method 3 is closely followed by method 1 where apart or whole mound is removed and the contents emptied in a container and given to IC. This method is less sustainable since subsequent harvest will wait for the mound to be rebuilt afresh. This method was most likely used by those who feel that termites are destructive to property and the continuous destruction of the mounds reduce damage caused by the termites to property by reducing the termite population.

On assessing the relationship between harvesting technique and socio-demographic characteristic, the finding shows no significant association between harvesting method employed by the respondents and the age, gender, education level and the occupation.

The findings however show a significant relationship between location and the type of method used for harvesting. This finding is in agreement with Dao et al., (2020) who indicated that the type of harvesting method varies from one region to the other.

M.subhylanus were harvested more times compared to the other termite species regardless of the harvesting technique used. This may be because *M.subhylanus* are more abundant than the others or because the harvesting techniques favoured them more as compared to the other species.

Additionally, the findings show no significant relationship between the termite type harvested and the harvesting method. This is in contrast with the finding by Hettie et al., (2019) who indicated that there is a relationship between harvesting method and the type of termite harvested.

5.5. Limitations of Use

Use of termites entails availability of labour to harvest the termites, knowledge on the type of termite, knowledge on the techniques for harvesting the termites, and the ability to employ these techniques to harvest significant quantities needed to provide nutrient to the IC.Farmers collect termites by various methods, however harvesting becomes a challenge when high quantities of termites are needed to feed large flock or when one needs to increase the proportion of protein in the diet. Abundance of termites depend on seasons and users are forced to walk long distances. This, coupled with lack of knowledge and time force farmers to stop feeding termites without looking for alternative protein source consequently causing IC to experience slow growth. Harvesting methods that involve destruction of mounds are not recommended not just for sustainability reasons but because the mounds play an important role in the functioning of African soil ecosystem.

Some termite species cannot be fed to chicks less than 2-4 weeks old. This is because they hurt and even kill chicks by biting their throat. However, identification of such harmful species can only be done by experienced users hence leaving out the ones without knowledge on how to identify the harmful termites.

5.6. Potentials of Use

Study shows that 72% of the respondents use termites for IC feeding. This means therefore that there is potential in upscaling and improving its use by the respondents since they already appreciate the need to include protein in the diets of IC. Given that the lack of knowledge in the collection and trapping techniques of termites was mentioned among the main reason for not using termites, it is clear that these techniques could be optimized and disseminated, which would improve IC nutrition and consequently improve the living standards of those who depend on it as a source of livelihood (Sankara et al., 2018).

Knowledge of a user friendly less intensive harvesting method could raise its usage. The capacity of the users should be built so that they are able to harvest adequate quantities and identify termite species that are harmful to chicks. The findings coronate with those of Sankara et al., (2020) who cited lack of knowledge in collection and trapping techniques, unavailability of termites and lack of time as main reasons for not using termites in Burkina Faso.

More awareness needs to be created to upscale its use among the small-scale IC keepers. Sustainable mound management is deemed key in upscaling usage of termites.

5.7. Nutrient Composition of *Macrotermes Subhylanus*

A study by Solomon et al.,(2020) showed that insects edible to both man and animals are good sources of protein and can meet the amino acid requirements of the consumers and are also rich in trace elements and vitamins. Edible grasshopper for example was found to contain CP of between 36-40% while that of raw *Macrotermes* species was found to be 42.3% (Ssepuuya et al., 2017).

Results of proximate analysis show that *M.subhylanus* is an important feed resource to IC. According to this study, *M.subhylanus* averagely contains CP level of 37.7%. A study by Akullo et al., (2018) found out a lower CP levels of 23.1% for *Macrotermes falciger* compared to this study. Additionally, according to Banjo et al., (2006)), *Macrotermes bellicocus* has CP level of 20.4% while *Macrotermes notalensis* has CP of 22.1%. A study by Moreki & Tiroesele (2012) reported crude protein content (% dry matter) of termites in Botswana as 46.3%.*M.nigeriensis* was found to contain 20.94% protein in a study carried out by CU et al., (2012) in Nigeria.

These results of CP analysis for *M.subhylanus* (37.7%) compares favorably with that of soya bean meal (39.28%) which is highly used all over the world as protein supplement for poultry. (Ssepuuya et al., 2017b). This shows that *M.subhylanus* can be used to replace the soya bean meal commonly used as an ingredient in poultry feeding and the major contributing factor to the high cost of animal feeds.

There are notably some differences between this study and the findings of other researchers. The variations could be attributed to different ecotypes, age, sex, feed among other factors (Akullo et al., 2018)

In this study, *M.subhylanus* were found to also contain calcium and phosphorus mineral elements. This coronate well with Akullo et al., (2018) who also found out the presence of these minerals in *Macrotermes falciger*.

The study by (Akullo et al., 2018) showed that *Macrotermes falciger* had both Ca and P levels at 81mg/100g. Another study by Moreki & Tiroesele (2012) found out the following as the mineral content of termites. Sodium- 0.20 (g)/100g), Calcium- 0.23(g/100g), Potassium- 0.38 (g/100g), Phosphorus- 0.38 (g/100g), Magnesium- 0.15 (g/100g). In this study, *M.subhylanus* were found to contain averagely 38.625mg/100g Ca and phosphorus level of 2.71mg/100g. A study by CU et al., (2012) on chemical analysis of *M.nigeriensis* found out the phosphorus levels of 14.90mg/100kg.

Birds and all animal species require minerals for basic functions of formation and replacement of skeleton. Calcium and phosphorus are additionally needed for the formation of eggshell in laying birds, for example, a laying bird deposits in eggshell about 40 times the Ca present in its own skeleton in one year of production (Elwinger et al., 2016).

With the Ca levels of 38.625mg/100g as found out by this study, *M.subhylanus* can supply the Ca requirements of the IC especially the laying ones. *M.subhylanus* in this study also contain averagely 4.6% crude fat; this is slightly lower as compared to a study by Moreki & Tiroesele (2012) who through proximate analysis found out higher figures of 7.3% in termites.

Proximate moisture composition shows that *M.subhylanus* are highly perishable due to the high moisture content at a mean of 8.5%. The dry mater content of *M.subhylanus* as per this study was 91.5%, however a study by Moreki & Tiroesele (2012) in Botswana got dry matter content for termites to be 96.4%

The average ash content of *M.subhylanus* harvested from the two study areas gave higher figures-19.95% as compared to other studies (Moreki & Tiroesele, 2012).

Further analysis showed significant differences at 5% significant level between *Macrotermes subhylanus* harvested from Township ward and those harvested from West Alego in terms of crude protein levels. *Macrotermes subhylanus* from township had higher CP level (39.4%) than those from West Alego which had CP level (36.1%).

Comparing the two regions, Township and West Alego, there was a significant difference in the chemical components: ash, dry matter, moisture, crude protein, phosphorus and calcium. However, the termite chemical composition, crude fibre and crude fat did not vary significantly across the two regions. Several studies on proximate analysis have tried to explain the variations in the nutrient composition. Józefiak et al., (2016) pointed out that protein content of insect meals vary considerably from around 40-60% even when the meals are based on the same insect species. This may be due to diversity in species, origin of the insect and the insect food substrate.

Taking into considerations the significant variations of some chemical components from this study, high preference would go for termites from West Alego if the interest was Ash, Dry matter, Phosphorus and Calcium since West Alego produced high averages for these components. Moreover, if the interest was in Moisture and Crude protein content, then Township is an ideal location. For interest on both crude fibre and crude fat, the two locations are indifferent. These can be outsourced form any location of preference.

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusion

This study was done in Alego Usonga to determine the demographic factors influencing the use of termites as protein supplement to IC as well as determining its suitability in terms of nutrient composition. A survey involving 218 respondents was done to determine the demographic factors influencing the use of termites and proximate analysis was also performed to determine the nutritional composition of the termites. Tests of association were used to determine the associations between utilisation of termites and the demographic variables. Occupation and age of the respondents were two factors that were expected to influence use of termites. The termites were also expected to be a good source of protein hence regarded as an important feed resource to IC.

It was found out that occupation and education level of the respondent had an association with the usage of termites as protein supplement. Location, gender and age of the respondents did not influence the usage of termites. Another test of association between harvesting method and the type of termite harvested did not reveal any association. The most common harvesting method is where a hole is made in the mound or near a mound with fresh leaves and collection is done after a few hours normally around 2-3 hours. *M.subhylanus* were harvested more times compared to the other termite species regardless of the harvesting technique used, this shows that compared to other termite species, *M.subhylanus* is readily available.

For termites to be fully utilized as feed, labour to harvest the termites, knowledge on the techniques for harvesting, knowledge on the type of termite and ability to combine these and collect quantities enough to provide nutrients to the birds must all be achieved.

The proximate analysis shows that *M.subhylanus* contain high CP levels that can continue to be used by IC as a source of cheap and alternative protein source. At an average level of 37.7% CP, the *M.subhylanus* compare favorably with soya meal that is widely used as an ingredient for animal feed. However, farmers of IC need to promote the use of *M.subhylanus* by adopting harvesting methods that can result into trapping of more termites. Once the termites are harvested, the chicks should be separated from the mature hens or fed separately since they require more protein for proper growth and development. Studies have shown that chicks end up not gaining access to enough termites when they are put together with the hens and cocks hence the slow growth rate. There is also need to increase the number of times that IC are fed on termites. Increasing the frequency of feeding to more than once a day may a have a positive influence on the productivity of the IC.

6.2. Recommendations

If termites are to be used effectively as a source of protein to IC.The following are recommended:

I. The state department of livestock development should consider developing guidelines on the exploitation and utilization of the *M.subhylanus* as an important feed resource to IC. The recommended dietary levels should be developed and disseminated to farmers for the same.

II. The stakeholders in the IC production and those in insect research should come up with ways of adding value to the termites through processing to increase their shelf life since proximate analysis show high moisture content indicating low shelf life.

6.3. Further Research

This research focused on the use of termites as protein supplement for indigenous chicken. It aimed at assessing the extent, limitations and potential of using termites as feed to IC. However, further research areas are suggested as follows.

1. A further investigation is needed to identify which termite species provide the most nutrients to IC.
2. An identification of termite species that are toxic to chicks of IC and the kind of damage or toxin produced.
3. An investigation should be done on what causes the difference in CP levels between termites of the same species in the study areas
4. Use of termites for IC feeding in other AEZ should be investigated.

REFERENCES

Adesina, K. (2012). Effect of Breed on the Composition of Cow Milk under Traditional Management. *J. Appl. Sci. Environ. Manage.*, *16*((1)), 55–59.

Akullo, J., Agea, J. G., Obaa, B. B., Okwee-Acai, J., & Nakimbugwe, D. (2018). Nutrient composition of commonly consumed edible insects in the Lango sub-region of northern Uganda. *International Food Research Journal*, *25*(1), 159–166.

Al-Qazzaz, M. F. A., Ismail, D., Akit, H., & Idris, L. H. (2016). Effect of using insect larvae meal as a complete protein source on quality and productivity characteristics of laying hens. *Revista Brasileira de Zootecnia*, *45*(9), 518–523. https://doi.org/10.1590/S1806-92902016000900003

Alemayehu, T., Bruno, J., Getachew, F., & Dessie, T. (2018). Socio-economic, marketing and gender aspects of village chicken production in the tropics: A review of literature. *International Livestock Research Institute*, 31.

Anankware, J. P., Fening, K., & Osekre, E. A. (2015). Insects as food and feed : A review. *International Journal of Agricultural Research and Review*, *Vol. 3*(1), 143–151.

Applegate, T. J., & Angel, R. (2014). *Nutrient requirements of poultry publication : History and need for an update*. *September*. https://doi.org/10.3382/japr.2014-00980

Banjo, A. D., Lawal, O. A., & Songonuga, E. A. (2006). The nutritional value of fourteen species of edible insects in southwestern Nigeria. *African Journal of Biotechnology*, *5*(3), 298–301. https://doi.org/10.5897/AJB05.250

Chromý, V., Vinklárková, B., Šprongl, L., & Bittová, M. (2015). The Kjeldahl Method as a Primary Reference Procedure for Total Protein in Certified Reference Materials Used in Clinical Chemistry. I. A Review of Kjeldahl Methods Adopted by Laboratory Medicine. *Critical Reviews in Analytical Chemistry*, *45*(2), 106–111. https://doi.org/10.1080/10408347.2014.892820

Culliney, T. W. (2013). Role of arthropods in maintaining soil fertility. In *Agriculture (Switzerland)* (Vol. 3, Issue 4). https://doi.org/10.3390/agriculture3040629

Daniel, G. D., & Emana, G. D. (2014). Preliminary studies on termite damage on rural houses in the Central Rift Valley of Ethiopia. *African Journal of Agricultural Research*, *9*(39), 2901–2910. https://doi.org/10.5897/ajar2014.8670

Dao, A. N. C., Sankara, F., Pousga, S., Coulibaly, K., Nacoulma, J. P., Ouedraogo, S., Kenis, M., & Somda, I. (2020). Traditional methods of harvesting termites used as poultry feed in Burkina Faso. *International Journal of Tropical Insect Science*, *40*(1), 109–118. https://doi.org/10.1007/s42690-019-00059-w

Duijn, A. P. van, Heijden, P. G. M. van, Bolman, B., & Rurangwa, E. (2018). *Review and analysis of small-scale aquaculture production in East Africa*.

Ebrahim, Y. (2018). *Chapter 3 (Research design) Part 2 (Research design stage 1 , 2 & 3) Section 2 methodology textbook on asse ... 3*(June).

Eike, B., Bas, H., Andrea Merino, M., & Xanthe, V. (2016). *Insects as livestock feed*.

Elwinger, K., Fisher, C., Jeroch, H., Sauveur, B., Tiller, H., & Whitehead, C. C. (2016). A brief history of poultry nutrition over the last hundred years. *World's Poultry Science Journal*, *72*(4), 701–720. https://doi.org/10.1017/S004393391600074X

Engel, M. S., Grimaldi, D. A., & Krishna, K. (2010). Termites (isoptera): Their phylogeny, classification, and rise to ecological dominance. *American Museum Novitates*, *3650*, 1–28. https://doi.org/10.1206/651.1

FAO. (2013). *6 . Nutritional value of insects for human consumption* (pp. 67–80).

FAO. (2014). Decision tools for family poultry development. In *FAO Animal Production and Health Guidelines No. 16. Rome, Italy*.

FAO, IFAD, UNICEF, WFP, & WHO. (2019). Food Security and Nutrition in the World 2019. In *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*.

FAO, & WHO. (2019). Nitrogen and protein content measurement and nitrogen to protein conversion factors for dairy and soy protein-based foods:a systematic review and modelling analysis. In *World Health Organization and Food and Agriculture Organization of the United Nations* (Vol. 4, Issue 1).

Foluke, A., Olufemi, A., Olabisi, F., & Adedotun, A. (2020). Evaluating the Participation and Productivity of Female Poultry Farmers in Iwo Local Government Area State of Osun …. *Researchgate.Net*, *April*. https://www.researchgate.net/profile/Foluke-Aderemi-2/publication/341050266_EVALUATING_THE_PARTICIPATION_AND_PRODUCTIVITY_OF_FEMALE_POULTRY_FARMERS_IN_IWO_LOCAL_GOVERNMENT_AREA_STATE_OF_OSUN_NIGERIA/links/5eaae09f299bf18b95891987/EVALUATING-THE-PARTICIPAT

Fróna, D., Szenderák, J., & Harangi-Rákos, M. (2019). The challenge of feeding the world. *MDPI*, *2017*.

Gad, M. F., Otieno, O. B., & Wahome, N. A. (2015). Factors Affecting the Performance of Small and Medium Scale Poultry Farming Enterprises in Karuri , Kenya. *Research Journal of Finance and Accounting*, *6*(19), 119–130.

GOK. (2012). Kenya Post-Disaster Needs Assessment (PDNA). 2008-2011 Drought. In *Government of Kenya (GOK) , Report by the Ministry of Finance.*

Henchion, M., Hayes, M., Mullen, A. M., Fenelon, M., & Tiwari, B. (2017). Future protein supply and demand: Strategies and factors influencing a sustainable equilibrium. *Foods*, *6*(7), 1–21. https://doi.org/10.3390/foods6070053

Hettie, B. A., Affedzie-Obresi, S., Gbemavo, D. S. J. C., Clottey, V. A., Nkegbe, E., Adu-Aboagye, G., & Kenis, M. (2019). Use of Termites by Farmers as Poultry Feed in Ghana. *MDPI*, *10*(3). https://doi.org/https://doi.org/10.3390/insects10030069

Igwe, C., Ujowundu, C., & Nwaogu, L. (2012). Chemical Analysis of an Edible African Termite, Macrotermes nigeriensis; a Potential Antidote to Food Security Problem. *Biochemistry & Analytical Biochemistry*, *01*(01), 1–4. https://doi.org/10.4172/2161-1009.1000105

Jouquet, P., Traoré, S., Choosai, C., Hartmann, C., & Bignell, D. (2011). Influence of termites on ecosystem functioning. Ecosystem services provided by termites. *European Journal of Soil Biology*, *47*(4), 215–222. https://doi.org/10.1016/j.ejsobi.2011.05.005

Józefiak, D., Józefiak, A., Kierończyk, B., Rawski, M., Świątkiewicz, S., Długosz, J., & Engberg, R. M. (2016). Insects - A Natural Nutrient Source for Poultry - A Review. *Annals of Animal Science*, *16*(2), 297–313. https://doi.org/10.1515/aoas-2016-0010

Kalinda, W., & Tanganyika, J. (2017). *Effects of protein levels on growth and laying performance of the Malawian indigenous chicken*. *4*(Table 2), 169–171. https://doi.org/10.15406/ijawb.2017.02.00037

Kelemu, S., Niassy, S., Torto, B., Fiaboe, K., Affognon, H., Tonnang, H., Maniania, N. K., & Ekesi, S. (2015). African edible insects for food and feed: Inventory, diversity, commonalities and contribution to food security. *Journal of Insects as Food and Feed*, *1*(2), 103–119. https://doi.org/10.3920/JIFF2014.0016

Kenis, M., & Hien, K. (2014). Prospects and constraints for the use of insects as human food and animal feed in West Africa. In *Insects to Feed the World* (Issue May).

Kenis, M., Koné, N., Chrysostome, C., Devic, E., Koko, G., Clottey, V., Nacambo, S., & Mensah, G. (2014). Insects used for animal feed in West Africa. *Entomologia*, *2*(2). https://doi.org/https://doi.org/10.4081/entomologia.2014.218

Kingori, A. M., Wachira, A. M., & Tuitoek, J. K. (2010). Indigenous chicken production in Kenya: A Review. *International Journal of Poultry Science*, *9*(4), 309–316.

Kinyuru, J., Kenji, G., & Njoroge, M. (2009). Process development, nutrition and sensory qualities of wheat buns enriched with edible termites (Macrotermes subhylanus) from Lake Victoria region, Kenya. *African Journal of Food, Agriculture, Nutrition and Development*, *9*(8). https://doi.org/10.4314/ajfand.v9i8.48411

Madhumita, P. (2021). *Gap between countries on animal protein consumption to widen by 2030: Report*. 109–118.

Magothe, T. M., Okeno, T. O., Muhuyi, W. B., & Kahi, A. K. (2012). Indigenous chicken production in Kenya: II. Prospects for research and development. *World's Poultry Science Journal*, *68*(1), 133–144. https://doi.org/10.1017/S004393391200013X

Malaisse, F. (2019). *Human termitophagy in Africa La termitophagie humaine en Afrique*. 1–24.

Moreki, J. C., & Chiripasi, S. C. (2012). Prospects of Utilizing Insects as Alternative Sources of Protein in Poultry Diets in Botswana: a Review. *J Anim Sci Adv J. Anim. Sci. Adv*, *2*(28), 649–658.

Moreki, J., & Tiroesele, B. (2012). Termite and earthworms as a potential alternative sources of protein for poultry. *International Journal for Agro Veterinary and Medical Sciences*, *6*, 368–376.

Moula, N., & Detilleux, J. (2019). A meta-analysis of the effects of insects in feed on poultry growth performances. *Animals*, *9*(5), 1–13. https://doi.org/10.3390/ani9050201

Muthoni, L. M. (2021). *MULBERRY (Morus alba) LEAF MEAL IN INDIGENOUS CHICKEN LAYER DIETS: EFFECT ON EGG PRODUCTION AND QUALITY*.

Mutungi, C., Irungu, F. G., Nduko, J., Mutua, F., Affognon, H., Nakimbugwe, D., Ekesi, S., & Fiaboe, K. K. M. (2019). Postharvest processes of edible insects in Africa: A review of processing methods, and the implications for nutrition, safety and new products development. *Critical Reviews in Food Science and Nutrition*, *59*(2), 276–298. https://doi.org/10.1080/10408398.2017.1365330

Naushad, K., Mahnoor, N., & Shah, F. (2020). Termites Economics and Control Aspects in Pakistan. *SSRN Electronic Journal*, *April*. https://doi.org/10.2139/ssrn.3583247

Njuguna, C. (2018). Impact of improved poultry production technologies among smallholder indigenous chicken farmers in Kakamega and Makueni– Kenya. *Journal of Chemical Information and Modeling*, *53*(9), 1689–1699.

Ntukuyoh, I., Edidiong, & Akpakpan, A. (2012). Evaluation of Nutritional Value of Termites (Macrotermes bellicosus): Soldiers , Workers , and Queen in the Niger Delta Region of Nigeria. *International Journal of Food Nutrition and Safety*, *1*(2), 60–65.

Pius, L. O., Strausz, P., & Kusza, S. (2021). Overview of poultry management as a key factor for solving food and nutritional security with a special focus on chicken breeding in east african countries. *Biology*, *10*(8). https://doi.org/10.3390/biology10080810

Pomalégni1, S. C. B., Gbemavo, D. S. J. C., Kpadé, C. P., Kenis, M., & Mensah, G. A. (2017). *Traditional use of fly larvae by small poultry farmers in Benin*. *October*. https://doi.org/10.3920/JIFF2016.0061

Prosekov, A. Y., & Ivanova, S. A. (2018). Food security: The challenge of the present. *Geoforum*, *91*(February), 73–77. https://doi.org/10.1016/j.geoforum.2018.02.030

Raphulu, T., Jansen, C., & Rensburg, V. (2018). *Dietary protein and energy requirements of Venda village chickens*. *119*(1), 95–104.

Saint Ville, A., Po, J. Y. T., Sen, A., Bui, A., & Melgar-Quiñonez, H. (2019). Food security and the Food Insecurity Experience Scale (FIES): ensuring progress by 2030. *Food Security, 11*(3), 483–491. https://doi.org/10.1007/s12571-019-00936-9

Sankara, F., Pousga, S., Dao, N. C. A., Gbemavo, D. S. J. C., Clottey, V. A., Coulibaly, K., Nacoulma, J. P., Ouedraogo, S., & Kenis, M. (2018). Indigenous knowledge and potential of termites as poultry feed in Burkina Faso. *Journal of Insects as Food and Feed*, *4*(4), 211–218. https://doi.org/10.3920/JIFF2017.0070

Shandukani, N., Kunjeku, E., & Duncan, F. (2018). Human uses and indigenous knowledge of edible termites in Vhembe District , Limpopo Province , South Africa. *South African Journal of Science*, *114*(1), 1–10.

Sogbesan, A. O., & Ugwumba, A. A. A. (2008). Nutritional Evaluation of Termite (Macrotermes subhyalinus) Meal as Animal Protein Supplements in the Diets of Heterobranchus longifilis (Valenciennes, 1840) Fingerlings. *Turkish Journal of Fisheries and Aquatic Sciences*, *8*(1), 149–158.

Solomon, Mariam D., Solomon, L. D., Jaryum, K. H., Dabak, J. D., & Sambo, S. H. (2020). Nutrient Potential and Economic Benefit of Varies Coleoptera (Grub Worm): Implication for Food Security. *EAS Journal of Nutrition and Food Sciences*, *2*(5), 217–221. https://doi.org/10.36349/easjnfs.2020.v02i05.001

Ssepuuya, G., Namulawa, V., Mbabazi, D., Mugerwa, S., Fuuna, P., Nampijja, Z., Ekesi, S., & Fiaboe, K. K. M. (2017). *Use of insects for fish and poultry compound feed in sub-Saharan Africa – a systematic review Abstract*. *3*(4), 289–302. https://doi.org/10.3920/JIFF2017.0007
\

Ssepuuya, G., Namulawa, V., Mbabazi, D., Mugerwa, S., Fuuna, P., Nampijja, Z., Ekesi, S., Fiaboe, K. K. M., & Nakimbugwe, D. (2017). Use of insects for fish and poultry compound feed in sub-Saharan Africa - A systematic review. *Journal of Insects as Food and Feed*, *3*(4), 289–302. https://doi.org/10.3920/JIFF2017.0007

Tang, C., Yang, D., Liao, H., Sun, H., Liu, C., Wei, L., & Li, F. (2019). Edible insects as a food source: a review. *Food Production, Processing and Nutrition*, *1*(1), 1–13. https://doi.org/10.1186/s43014-019-0008-1

Tiroesele, B., & Moreki, C. (2012). Termites and Earthworms As Potential Alternative Sources of Protein for Poultry. *International Journal for Agro Veterinary and Medical Sciences*, *6*(5), 368. https://doi.org/10.5455/ijavms.174

Tomiyama, J. M., Takagi, D., & Kantar, M. B. (2020). The effect of acute and chronic food shortage on human population equilibrium in a subsistence setting. *Agriculture and Food Security*, *9*(1), 1–12. https://doi.org/10.1186/s40066-020-00261-x

van Huis, A. (2017). Edible insects and research needs. *Journal of Insects as Food and Feed*, *3*(1), 3–5. https://doi.org/10.3920/JIFF2017.x002

van Huis, A. (2020). Insects as food and feed, a new emerging agricultural sector: A review. *Journal of Insects as Food and Feed*, *6*(1), 27–44. https://doi.org/10.3920/JIFF2019.0017 van Huis, Arnold. (2017a). Cultural significance of termites in sub-Saharan Africa. *Journal of Ethnobiology and Ethnomedicine*, *13*(1), 1–12. https://doi.org/10.1186/s13002-017-0137-z

van Huis, Arnold. (2017b). Cultural significance of termites in sub-Saharan Africa. *Journal of Ethnobiology and Ethnomedicine*, *13*(1), 1–12. https://doi.org/10.1186/s13002-017-0137-z

Wambui, C. C., Njoroge, E. K., & Wasike, C. B. (2018). Characterisation of physical egg qualities in indigenous chicken under free range system of production in Western Kenya. *Livestock Research for Rural Development*, *30*(7).

Wondmeneh, E., Van derWaaij, E. ., Udo4, H. M. J., Tadelle, D., & Van Arendonk, J. A. M. (2016). Village poultry production system: Perception of farmers and simulation of impacts of interventions. *African Journal of Agricultural Research*, *11*(24), 2075–2081. https://doi.org/10.5897/ajar2015.10493

APPENDICES

Appendix I: Household questionnaire 1

HOUSEHOLD QUESTIONNAIRE **THE USE OF TERMITES AS PROTEIN SUPPLEMENT FOR INDIGENOUS CHICKEN IN SMALL HOLDER FARMS**	
1. Geographic information	
County:	Sub County:
Ward:	Location:
Age of respondent:	Gender of respondent:
Name of Enumerator:	Date of data collection: (DD/MM/YY)
Questionnaire number:	Name of respondent:
2. Introduction and Consent	
Hello, my name is .... I am collecting data for Caroline Okwiri, an MSC student at Jaramogi Oginga who is seeking to understand more on the use of Termites as protein supplement for Indigenous Chicken in small holder farms. I intend to ask you questions about the use of termites and also about your household. The data collected will assist in assessing the use of termites as protein supplement to Indigenous Chicken and to determine if the quantities harvested and fed to the birds is adequate to provide the protein requirements to the birds for growth and production.	

INSTRUCTION: The primary person to be engaged as respondent will be the adult family member responsible for the Indigenous Chicken keeping at the household. If absent, their representative shall be interviewed and he or she shall be above 18 years

ONSENT: The Interview shall take 20-30 minutes. I request for your name but your respo

hall be treated with confidentiality. The data shall be shared to a **Yes** owledge o **NO**

ermites as protein supplement for Indigenous Chicken.

o you accept to participate in this interview?

SECTION 3: SOCIO-DEMOGRAPHIC FACTORS			
3.1	What is your occupation?		
3.2	Are you an Indigenous Poultry farmer	Yes	1
		No	2
3.3	What is your main source of income?	Regular employment	1
		Agricultural production crops	2
		Agricultural production livestock	3
		Casual work	4
		Others	5
3.4	What are the other sources of income apart from the main source?	Regular employment	1
		Agricultural production	2

		crops		
		Agricultural production livestock		3
		Casual work		4
		Others		5
	What is your highest level of education?	None		0
		Primary		1
		Secondary		2
		College		3
		University		4
	What is the size of your farm land holding in acres?			
	Who owns the land?	Self		1
		Spouse		2
		Rented		3
	Mode of land ownership	Communal		1
		Free hold		2
		Rented		3
	What is the size of your Household? (Include all dependents staying in yourhousehold)	Size of Household		
	What is your religion?	Christian		1
0		Protestant		
		Christian Catholic		2
		Muslim		3
		Others – Specify		4
4	**SECTION 4. LIVESTOCK PRODUCTION**			
4.1	What types of livestock do you keep?	Cattle		1
		Sheep		2
		Goats		3
		Poultry		4
		Others, Specify		5
4.2	What are the main reasons for rearing theseanimals?			
4.3	Which livestock contributes significantly tohousehold food security?	Cattle		1
		Sheep		2
		Goat		3
		Poultry		4

5	**CHICKEN PRODUCTION**					
	What is your chicken population					
	Type of chicken	Size of flock (fill in the number of stock held by the farmer)				
		Cocks	Hens	Chicks	TOTAL	
5.1	Indigenous chicken					
	Broilers					
	Layers					
	Improved kienyeji					
5.2	What is your reason for keeping Indigenous Chicken?			Eggs	1	
				Meat	2	
				Income	3	
				Rituals	4	
				Prestige	5	
				Others specify	6	
5.3	Which is the order of reasons for your keeping Indigenous Chicken (in the order of Priority)			Eggs	1= Top reason, 6 least reasons	
				Meat	1= Top reason, 6 least reasons	
				Income	1= Top reason, 6 least reasons	
				Rituals	1= Top reason, 6 least reasons	
				Prestige	1= Top	

			reason, 6 least reasons	
		Others specify	1= Top reason, 6 least reasons	
6	**IMPORTANCE OF INDIGENOUS CHICKEN**			
6.1	How long have you been farming Indigenous Chicken? (Months)		Months	
6.2	Who owns the Indigenous Chicken in the household?		Wife	1
			Husband	2
			All	3
6.3	Who is responsible for the management of the Indigenous Chicken?		Wife	1
			Husband	2
			Children	3
			All	4
	Importance of Indigenous Chicken			
6.4	How many Indigenous Chicken have you bought since December 2018 to date			
6.5	Total cost of purchasing the Indigenous Chicken since December 2018 to date (in Kenya Shillings)			
6.6	Number of Indigenous Chicken sold since December 2018 to date			
6.7	Total cost of Indigenous Chicken sold since December 2018 to date (in			
	Kenya Shillings)			
6.8	Number of Indigenous Chicken slaughtered for household use since December 2018 to date			
6.9	Total cost of Indigenous Chicken slaughtered for household use since December 2018 to date (in Kenya Shillings)			
6.10	Average eggs produced by the Indigenous Poultry in a year			

	What do you think can be done to improve the contribution of IC to household food security, nutrition and income?				
	In which season do you most experience the following challenges in Indigenous Chicken production				

	Challenge			Season (Dry =1, Rainy=2)
	Feed shortage			
	Diseases			
	External parasites			
	Internal parasite			
	Theft			
	Predation			
	Limited market access			
	Housing			
	Others specify			
7	**INDIGENOUS CHICKEN NUTRITION**			
7.1	Have you ever been trained on poultry nutrition?		Yes=1, No =2	
7.2	Do you practice supplementary feeding to your chicken with available feed resources?		Yes=1, No =2	
7.3	Which method do you use when doingsupplementary feeding of Chicken?	Broadcasting		1
		Through feeders		2
		Other means (Specify)		
7.4	How do you feed your chicken when doing thesupplementary feeding	All Chickens together		1
		Chicks alone		2
		Chicks and Hens		3
		Others specify		4
7.5	Which season do you mostly provide extra feed for your Chicken?			Dry season=1
				Rainy season=2
7.6	Do chicken finish the entire feed supplement given to them		Yes=1, No =2	
7.7	If no, what happens to the non-completed feedsupplement offered to the Chicken?			
7.8	What do you use in supplementing your Chicken feed			
7.9	When do you normally supplement?	Mid- mornin g beforescaveng ing=1		1
		Mid- day during Scaven ging=2		2
		Evening		3

		after Scaven ging =3	
	If you don't give supplement, kindly give reasons why		
	What do you think are the main constraints in chicken feeding?		
	Have you experienced feed shortage in the past 12 months?	Yes=1, No =2	
	If yes, in which season did you experience the feed shortage	Dry season= 1	
		Rainy season= 2	
	Do you give water to your birds?	Yes=1, No =2	

8	**KNOWLEDGE ABOUT THE USE OF INSECTS AS POULTRY FEED**		
	Do you know that chicken scavenge for insects and	Yes=1, No=2	
	worms?		
	Do you use termites to supplement Indigenous Chicken?	Yes=1, No=2	
	What is your main reason for giving termites?		
	Which ages of Chicken do you give termites	All ages=1	
		Chicks only =2	
		Adult Chickens only =3	
	Are termites available throughout the year?	Yes=1, No=2	
	If no, when in the year are they available?		
	How many times a week do you give termites?		
	How many times a day do you give termites?		
	What time of the day do you give termites to your chicken?	Mornin g before scaveng ing =1	
		Mid- day during Scaven ging=2	
		Evening	
		after Scavenging =3	
	Where do you get the termites for chicken feeding?	Purchase from others= 1	
		Own harvest =2	
	How do you harvest or capture the termites? *(Method one: Whole or part of the mound is removed usingan axe or hoe* *Method two: A pot or container with organic matter isinverted over trails and small nests. Method three: A hole is made in the mound with fresh leaves.Method four: Involves removing part of the mound and waiting for around 5 hours before returning to collect the newly rebuilt part of the mound which is full of termites Method five: A hole is made in the mound until the farmer reaches the fungus garden (has white colour) and a basket isplaced on the hole created, debris collected into a basket and covered with leafes for 2 hours method six: Others, Describe*	Harvesting Method 1=1	
		Harvesting Method 2=2	
		Harvesting Method 3=3	

	Where do you harvest the termites from?	Own land =1	
		Other people's land =2	
		Own land and other peoples land =3	
	How do you manage termite mounds?		
	What are the local names for the termite species harvested?		
	Do you think the quantity of termites you give is adequate for poultry nutrition? Give reasons		
	What are the challenges for using termites as poultry feed?		
	What can farmers do to effectively use Termites as animal feeds?		
	What observations have you made on the positive effects of feeding termites to indigenous chicken?		
	Are all termites good as feed supplements?	Yes=1, No =2	
	If no, which termites are not good as Chicken feed supplements? (Local names or descriptions of the termites)		
	Why are they not good as Chicken feed supplements?		
	Do you use other insects other than termites in supplementing your Chicken feed?	Yes=1, No=2	
	If yes, which are these insects?		
	If you don't use any insect as feed supplement for indigenous Chicken, kindly give reasons why		
8.2	Would you recommend any insect for use as Chicken feed supplement? If yes why and which insect?		

Thank you for your participation

Appendix II: Approval Letter from Ethics Review Committee

JARAMOGI OGINGA ODINGA
UNIVERSITY OF SCIENCE AND TECHNOLOGY

DIVISION OF RESEARCH, INNOVATION AND OUTREACH
JOOUST-ETHICS REVIEW OFFICE

Tel. 057-2501804
Email: erc@jooust.ac.ke
Website: www.jooust.ac.ke

P.O. BOX 210 - 40601
BONDO

OUR REF: JOOUST/DVC-RIO/ERC/E3

19th June, 2021

Caroline Majuma
Adm. No. A451/4267/2018

Dear Ms. Majuma,

RE: APPROVAL TO CONDUCT RESEARCH TITLED "THE USE OF TERMITES AS A PROTEIN SUPPLEMENT FOR INDIGENOUS CHICKEN ON SMALLHOLDER FARMS"

This is to inform you that JOOUST ERC has reviewed and approved your above research proposal. Your application approval number is **ERC/19/6/21-29.** The approval period is from 19th June, 2021 – 18th June, 2022.

This approval is subject to compliance with the following requirements:

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations and violations) are submitted for review and approval by JOOUST IERC.
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to NACOSTI IERC within 72 hours of notification.
iv. Any changes, anticipated or otherwise that may increase the risks of affected safety or welfare of study participants and others or affect the integrity of the research must be reported to NACOSTI IERC within 72 hours.
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to JOOUST IERC.

Prior to commencing your study, you will be expected to obtain a research permit from National Commission for Science, Technology and Innovation (NACOSTI) https:oris.nacosti.go.ke and also obtain other clearances needed.

Yours sincerely,

Prof. Francis Anga'wa
Chairman, JOOUST ERC

Copy to: Deputy Vice-Chancellor, RIO   Director, BPS   Dean, SAFS

Appendix III: Approval Letter from Board of Postgraduate Studies

JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE & TECHNOLOGY

BOARD OF POSTGRADUATE STUDIES

Office of the Director

Tel. 057-2501804
Email: bps@jooust.ac.ke

P.O. BOX 210 - 40601
BONDO

Our Ref: A451/4267/2018

Date: 27th August 2020

TO WHOM IT MAY CONCERN

RE: CAROLINE MAJUMA - A451/4267/2018

The above person is a bonafide postgraduate student of Jaramogi Oginga Odinga University of Science and Technology in the School of Agricultural and Food Sciences pursuing Master of Science in Food Security and Sustainable Agriculture. She has been authorized by the University to undertake research on the topic: ***"The Use of Termites as a Protein Supplement for Indigenous Chicken on Smallholder Farms".***

Any assistance accorded to her shall be appreciated.

Thank you.

JARAMOGI OGINGA ODINGA
DIRECTOR BOARD OF
POST GRADUATE STUDIES
DATE ....
P. O. BOX 210 - 40601 BONDO
UNIVERSITY OF SCIENCE & TECHNOLOGY

Prof. Dennis Ochuodho
DIRECTOR, BOARD OF POSTGRADUATE STUDIES