POTENTIAL OF ALATE TERMITES (*Macrotermes Sp.*) AS AN ENTERPRISE TO IMPROVE FOOD SECURITY AMONG HOUSEHOLDS

ANYUOR SAMANTHA AKOTH

A Research Thesis Submitted to The School of Agricultural and Food Sciences in Partial Fulfilment of the Requirements for Award of Degree of Master of Science in Food Security and Sustainable Agriculture of Jaramogi Oginga Odinga University of Science and Technology (JOOUST)

OCTOBER, 2022

DECLARATION

This thesis is my original work and has not been presented for an award of a diploma or conferment of degree in this or any other University.

Signature…  Date…2/10/2022.

ANYUOR, SAMANTHA AKOTH

Reg: **A451/4256/2018**

RECOMMENDATION

This thesis has been submitted for examination with our approval as University Supervisors.

Signature……. Date…….…….

Prof. MONICA A. AYIEKO.

Department of Plants, Animal and Food Sciences.

Jaramogi Oginga Odinga University of Science and Technology.

Signature  Date: 2/10/2022

Dr. DEBORAH RUTH AMULEN.

Department of Livestock Industrial Resources.

Makerere University.

DEDICATION

This thesis is dedicated to God and to my parents.

ACKNOWLEDGEMENT

First, I thank God for the gift of life, strength, patience, and determination He granted me throughout the research period. I express my gratitude to Jaramogi Oginga Odinga University of Science and Technology for enrolling me to pursue Master of Science in Food Security and Sustainable Agriculture. I also acknowledge the support from the INSEFOODS through World Bank to carry out the research.

I thank my principal supervisor, Prof. Monica Ayieko for her valuable guidance, advice, and encouragement in writing a paper and this thesis. The valuable comments she made as an academic advisor and her patience with me throughout the study has been remarkable. My gratitude also goes to my second supervisor, Dr. Deborah Amulen for sharing her extensive knowledge, guidance, support, and motivation throughout the research period.

I have the courage to express my sense of gratitude and regards to my parents Mr. and Mrs Raphael Anyuor for the financial and moral support they gave towards this research. I thank my fellow students and friends for their unfailing support throughout the study, not forgetting the support from Mr. Alpha Masemba. I also thank the enumerators for assisting me during data collection. I am grateful to the households for their participation in this research and to everyone who made any contribution towards successful completion of this thesis.

ABSTRACT

Rising demand for high value protein is expected to double by 2050. To meet the new demand, conventional livestock may prove expensive and unsustainable, calling for research on alternative sources of protein, hence a switch to affordable and environmentally acceptable protein sources. Previously, Alate termites have been considered as a potential source protein and household income. However, information on utilization and how commercialization impacts livelihoods at household level is largely anecdotal and sparse. This study sought to partly fill this knowledge gap by assessing the capacity of households on collection, consumption, and commercialization of the alate termite. The research was a cross-sectional survey designed to target a population of 64,752 households in Vihiga County. Semi-structured questionnaire was used to collect data from a sample of 204 households obtained through multistage sampling procedure. Descriptive and exploratory statistics were applied to summarize the results, while multivariable regression models were used to predict the likelihood of termite utilization in improving household income and food security. Our results suggest a strong association between the respondent's socio-economic status and capacity to utilize alates, including willingness to consume, knowledge of utilization purposes and rate of commercialization. Availability of alate termites influenced their role in alleviating hunger through household income diversification and food security index ($p=0.045$). The average retail price per kilogram KES 500, compared favourably to the price of goat meat, which retailed in region. The average price per kilogram increases from collectors to wholesale traders and to retailers. The trade was dominated by women and characterized by wholesalers who buy the alates from collectors and sell to retailers. There was a significant influence of decision on utilization purposes on the supply benefits derived from alate termites. The main challenge to alate termite commercialization were seasonality and missing links in high-rate value addition sector. Likewise, cumulative impacts of overexploitation, unsustainable harvesting methods and land transformation could threaten this enterprise. Therefore, possibility of value addition should be promoted to enhance the shelf life and improve the market value. The study recommends training of the mass on sustainable harvesting methods to minimize species extinction rate.

Key words; Alate termites, Food security, utilization, Livelihood

TABLE OF CONTENT

DECLARATION ..... **ii**

RECOMMENDATION ..... **ii**

DEDICATION ..... **iii**

ACKNOWLEDGEMENT ..... **iv**

ABSTRACT ..... **v**

TABLE OF CONTENT ..... **vi**

LIST OF TABLES ..... **x**

LIST OF FIGURES ..... **xi**

ABBREVIATIONS AND ACRONYMS ..... **xii**

CHAPTER ONE **1**

INTRODUCTION **1**

1.1 Background Information 1

1.2 Statement of the Problem 5

1.3. Objectives of the Study 5

1.3.1 General Objective 5

1.3.2 Specific Objectives 5

1.4 Research Questions 6

1.5 Justification of the Study 6

1.6 Operational Definition of Terms 7

CHAPTER TWO **8**

LITERATURE REVIEW **8**

2.1 Overview of Entomophagy 8

2.2 Global View of Food Security 9

2.3 Food Security Situation in Vihiga County 9

2.4 Household Livelihood Promotion and Diversification 10
2.5 Harvesting of Termites 11
2.6 Overview of Termite utilization 12
2.6.1 Nutritional Value of Termites 13
2.6.2 Attitude towards Termite Utilization 14
2.6.3 Utilization of alate Termites for Livelihood Promotion 14
2.7 Theoretical and Conceptual Framework 16
2.7.1 Theoretical Framework 16
2.7.2 Conceptual Framework 17
CHAPTER THREE 19

RESEARCH METHODOLOGY 19

3.1 Introduction 19
3.2 Description of the Study Area 19
3.3 Research Design 21
3.4 Target Population 21
3.5 Sampling Procedure 21
3.6 Sample Size Determination 21
3.7 Research Instrument 23
3.8 Pre-testing of the Research Instrument 23
3.9 Reliability of the Instrument 23
3.10 Validity of the Instrument 23
3.11 Data Collection Procedure 24
3.12 Ethical Considerations 24
3.13 Data Analysis Procedure 24
3.13.1 Households' Capacity for Termite Collection and Utilization in the Community 25
3.13.2 Termite Collection and Marketing to Household Income for Improved Household Livelihood 25
3.13.3 Contribution of Alate Termite Collection, Marketing and Utilization to ..26
CHAPTER FOUR 28

RESULTS AND DISCUSSIONS 28

4.1 Introduction..... 28
4.2 Results 28
4.2.1 Descriptive Statistics.....28
4.2.2 Households Capacity 29
4.2.2.1 Consumption of Alate Termites 29
4.2.2.2 Purposes of Alate Termite Utilization.....30
4.2.2.3 Knowledge and Practices on Alate Termite Harvesting.....32
4.2.3 Collection and Commercialization of Alate Termites 33
4.2.3.1 Marketing of Alate Termites.....33
4.2.3.2 Profitability of Alate Termite Enterprise.....33
4.2.4 Contributions of Alate Termites to Household Food Security.....35
4.3 Discussions 38
4.3.1 Households' capacity for Collection and Utilization of alate Termites.....38
4.3.1.1 Consumption of Alate Termites 38
4.3.1.2 Awareness of Purposes of Alate Termite Utilization.....39
4.3.1.3 Harvesting of Alate Termites.....41
4.3.1.4 Factors Influencing Abundance of Alate Termites 43
4.3.2 Marketing of Alate Termites and Household Livelihood diversification....44
4.3.2.1 Collection and Marketing of Alate Termites 44
4.3.2.2 Profitability of Alate Termite Enterprise.....45
4.3.2.3 Alate Termites as A Source of Livelihood Diversification 46
4.3.2.4 Constraints to Commercialization of Alate Termites.....47
4.3.2.5 Capacity Building Intervention for Marketers.....48
4.3.3 Contributions of alate Termites to Household Food Security.....49
4.3.3.1 Availability of alate termites.....49
4.3.3.2 Affordability of The Alate Termites.....50
CHAPTER FIVE.....54

CONCLUSIONS AND RECOMMENDATIONS 54

5.1 Introduction..... 54
5.2 Conclusion 54
5.3 Recommendation 55
5.4 Recommendations for Further Studies..... 56
REFERENCES.....57

APPENDICES 70

Appendix 1: Questionnaire 70
Appendix 2: NACOSTI Research Permit 76
Appendix 3: JOOUST ERC Approval 77
Appendix 4: JOOUST BPS Authorization Letter 78
Appendix 5: SPSS Variable Computation Script 79
Appendix 6: Sample R-script for Pearson's Chi square tests 80

LIST OF TABLES

Table 1: Percentage of Most Consumed Insects 8
Table 2: Distribution of sample per the sub-counties.....22
Table 3:Definition of variables used in regression model 27
Table 4:Socio-demographic Descriptive Statistics.....28
Table 5: Summary of rate of Respondents Involvement in Alate termite collection, consumption, and marketing. 29
Table 6:Association between selected demographic variables and forms of alate termites' preparation. 30
Table 7:Association between alate termite utilization purposes and selected demographic variables 31
Table 8:Association between alate termite abundance variance and selected demographic variables 33
Table 9: Input-output data for gross margin computation 34
Table 10: Summary of the Estimates of the Regression Parameters.....35
Table 11: Measure of Utilization of alate Termites using Food Security Indicators ...36
Table 12: Association between selected demographic characteristics and extent of termite utilization for food security.....36
Table 13: The influence of termite utilization purpose, abundance variance, quantity sold, and income generated on food security.....37

LIST OF FIGURES

Figure 1: Conceptual Framework.....18
Figure 2: Map of the Study Area.....20
Figure 3:Percentage of utilization purposes.....31
Figure 4: Factors influencing Abundance of late Termites. 32
Figure 5: Supply chain of alate termites in Vihiga County 45

ABBREVIATIONS AND ACRONYMS

FAO	Food Agriculture Organization
GHGE	Green House Gas Emission
INFOODS	International Network of Food Data System
LD	Livelihood Diversification
NA	North America
NMP	Neo-Malthusian Perspective
NTFP	Non-Timber Forest Product
SDGs	Sustainable Development Goals
SLT	Social Learning Theory
TLT	Traditional Learning Theory.

CHAPTER ONE
INTRODUCTION

1.1 Background Information

Over the last decade, the demand for animal-based protein has rapidly increased, due to the global preference for meat(57%) and milk (48%) (Aiking, 2011; Kim et al. 2019). This has further been exacerbated by the rise in human population that is projected to reach 9.6 billion by the year 2050 (Bongaarts, 2009). According to the United Nations Food and Agriculture Organization (UN-FAO), 824 million people in the world do not have enough to eat. Currently there is rise in the number of undernourished people in the last four years which reached 820 million in 2017, contributing to 10.9% prevalence of the global undernourishment (Popp et al. 2019; FAO, 2018). In Africa, most recent estimates show that 281.6 million people on the continent, nearly one-fifth of the population, are faced with hunger (FAO, 2018). This is attributed to reduced agricultural productivity, change in lifestyles and eating habits.

In Africa, prevalence of undernourishment has risen from 20.8 in 2015 and currently standing at about 23.2% (FAO, 2017). Of which, Sub-Saharan Africa accounts for 25% of the 815 million people who are undernourished in the world. This indicates cases of severe food insecurity is increasing in almost all regions in Sub-Saharan Africa (Turk, 2016). Similarly, prevalence of undernourishment is reportedly on the rise in Eastern Africa at 20.8% except in Djibouti (World Bank, 2018). Selected countries like Ethiopia, Kenya and Uganda have rates projected at 28.6%, 19.3% and 39% respectively. This could be due to conflicts and poverty that limit food access at the household level.

Kenya, like other developing countries, is faced with cases of food insecurity with approximately 3.4 million people in 2017 being acutely food insecure (GoK, 2017). This is attributed to increased population growth and urbanization resulting in high demand for food, especially animal-based protein (FAO, 2013). The food supply tends to decline because of pressure on the agricultural land for settlement and reduced agricultural productivity resulting from climate change (FAO, 2009; Odhiambo, Wasike & Ogindo 2019). This calls for a need to implement and scale up interventions aimed at guaranteeing access to nutritious food and breaking of the intergenerational

cycle of malnutrition and food insecurity. Moreover, the dilemma is on how to ensure the demand for animal-based protein is met in the face of climate change, environmental degradation, and exploitation (Kim et al. 2019).

Presently, food production systems places heavy burden on the environment in terms of emissions, of which in Kenya, the agricultural sector is responsible for about 56% of the total country's emissions (IPCC 2006; GoK, 2013). Reducing the threats and burden on the environment would entail reducing the rate of conventional livestock production by a smaller percentage to cut on the overall agricultural emissions by 5% in 2030 (UNEP, 2012). Consequently, the goal of environmental sustainability and meeting the increasing demand for protein, calls for exploration of alternative protein sources.

The most commonly available sources of animal based protein include, milk, meat and eggs whose supply remains expensive and unsustainable (World Bank, 2017; GoK, 2013). Therefore, high-value edible insects are one of the alternative food sources considered to supplement animal-based protein. Entomophagy, the capture and consumption of insects, could be a viable solution for underdeveloped countries, such as Kenya (van Huis, 2013). Research is on the rise to assess possible prospects in use of edible insects as a source of protein (Amadi & Kiin-Kabari 2016; Seni, 2017). Edible insects are efficient in terms of production as they have a short reproduction cycle, require less water and land, emits less greenhouse gases and can feed on bio wastes (FAO, 2013; Van Huis, 2016).

Edible insects are potential source of protein (amino acids), fats, minerals and essential vitamins including vitamin A, B complex and C (Kinyuru et al. 2013). They pose low risks of zoonosis while providing high entrepreneurial opportunities for the global population (Ayieko et al. 2011). Furthermore, edible insects have the potential and significance as future food and feed alternatives with high nutritional value and a lower ecological footprint (FAO, 2013). Therefore, focus is on the supply side to establish and optimize insect production, as well as to develop a functional edible insect value chain.

Nevertheless, entomophagy contributes positively to nutrition, health, environmental sustainability, and household livelihood for those involved in the edible insect value chain (Kisaka, 2018). Collection and consumption of insect dates back to prehistory as a source of essential nutrients required in the human diet (Jumbe et al. 2008; Anankware et al. 2016). However, entomophagy is dependent on the availability of edible insects and the ability to collect them, as well as the cultural beliefs and customs that surround their consumption in various parts of the world (Kinyuru et al. 2010; Olum et al. 2021).

More than 2.5 billion people in Africa and Asia consume insects as part of their diet and sell them for a living in both rural and urban areas (FAO, 2010). Variety of edible insect species are consumed in Asia, South Africa (SA), North America (NA), Africa, and Australia, with SA, NA, and Asia ranked first, second, and third, respectively (Anankware et al. 2016). Entomophagy has been reported in Africa, where mostly the insects are collected from the wild and used either as livestock feed or for food (van Huis, 2013). Currently, about 1,900 insect species are consumed worldwide these include caterpillars *(lepidoptera*) 18%, bees, wasps and ants (*Hymenoptera*) (14%), grasshoppers, locusts and crickets (*Orthoptera*) (13%), cicadas, leafhoppers, plant hoppers, scale insects and true bugs (*Hemiptera*) (10%), termites (Isoptera) (3%), dragonflies (*Odonata*) (3%), flies (*Diptera*) (2 %) and other orders (5%) (FAO, 2013; van Huis, 2013; Jongema, 2017).

Termites are the most seasonally collected and consumed insects as important part of the diets in parts of western province in Zambia (Igwe et al. 2011). The consumption of the soldier termites of the *Macrotermes spp* has been documented in Zimbabwe and other parts of Sub-Saharan Africa (Van Huis, 2003). In Kenya, several insect species including the alate termites, grasshoppers, locusts, lake flies and crickets have been embraced as important parts of the diet (Ayieko 2014; Kinyuru et al. 2012). These insects have received a boost due to increased research on their nutritional and economic potentiality (Adepoju et al. 2021). Similarly, termite collection and consumption has been reported in larger parts of Western Kenya and the lake region, with alate termites being the most commonly harvested at the start of the first rains following a dry season (Ayieko et al. 2010 ; Ghosh et al. 2020).

Termites are collected for sale in open markets in various countries in Africa including Zambia and Uganda as source of household income. In Kenya, marketing has been concentrated in a few counties in the western region (Kisaka, 2018). Termites are sold in whole after frying or in processed products such as crackers, muffins, sausages, and meat loaf. This allows marketers to diversify their sources of income while households gain access to a balanced diet, revealing its potential for food security and a source of household income (Ayieko et al. 2010). Termites and termite products are accepted by a larger population in Kenya's lake region. Therefore, there is need to assess the contributions to economic and nutritional aspects by assessing the households that are already benefiting from termite utilization.

Vihiga county is characterized by small scale crop and livestock production which predisposes the population to cases of food insecurity and malnutrition (GoK, 2013). Additionally, a report by the county development plan of (2018-2022) indicates that the county faces a challenge of malnutrition resulting in stunting, wasting and underweight of approximately 21% of children population under the age of five (Oduor et al. 2019). Therefore, diversification of food resources and promotion of value chain activities of the available food resources would promote employment to contribute to household cushioning techniques against poverty, hunger and promote food security

Cases on acceptance and willingness to consume termites have been reported (Ayieko et al. 2010; Netshifhefhe, Kunjeku, & Duncan, 2018). However, potential of termites to contribute to household food security and benefits of utilization to a household in terms of economic aspects remains unexplored area of research. Therefore, this study focused on how utilization of alate termites contributes to household food security and livelihood diversification to make recommendations on its profitability and potentiality as an enterprise.

1.2 Statement of the Problem

Rural populations in developing countries such as Kenya, are faced with food insecurity and malnutrition despite the existing food variety (Ogello, & Munguti, 2016; Ruel et al. 2017; Momanyi et al. 2019). This is due to overreliance on rain-fed agriculture, animal-based protein which are expensive and unsustainable. Concerningly, diets of various households in Vihiga County are not diverse given the untapped potential of local food biodiversity, low living standards resulting into rise in cases of malnutrition (Oduor et al., 2019). This has propelled many households to consume edible insects such as alate termites as dietary curtailments. Despite the nutritional (good source of crude protein of about (46%) and other beneficial nutrients) and economic potential of the alate termites, the value chain continues to receive limited attention (harvesting, consumption, and marketing), even though there is a shift from subsistence to commercialization (Muimba-Kankolongo et al. 2015). Therefore, there is need to tap information on attitude, knowledge, and practices of alate termite utilization that is important for ensuring livelihood diversification options as well as informing on the household food security situation. The study was undertaken to better document the alate termite consumption, harvesting and marketing as an income-generating activity and lastly, assessed its contribution to food security.

1.3. Objectives of the Study

1.3.1 General Objective

The overall objective of this study was to generate knowledge on collection and utilization of alate termites and determine its potentiality as an enterprise to improve households' food security in Vihiga County.

1.3.2 Specific Objectives

i. To assess households' capacity for termite utilization in the community.
ii. To quantify the extent of termite marketing and income generation for improved household livelihoods.
iii. To determine the contribution of alate termite collection, marketing, and utilization to household food security.

1.4 Research Questions

i. Do households have the capacity for termite utilization in the community?
ii. How much income do households obtain from alate termite marketing for improved livelihoods?
iii. To what extent does termite collection, marketing and utilization contribute to household food security?

1.5 Justification of the Study

Entomophagy has gained prominence due to insect efficiency in feed conversion rate, low risks of greenhouse gas emissions (GHGE) and potential supply of essential minerals. The expansion of the insect value chains especially alate termites could enhance food security among households. This could be explored as an alternative entity for livelihoods diversification through collection, marketing, and achievement of good nutrition. The utilization of alate termites increases the quantity and quality of food available that is affordable to consumers alongside the conventional sources. This could possibly boost the living standard among households as source of food and income. In turn this contributes towards ensuring household food security inscribed in the sustainable development goals (SDGs) is met. The study focused on the profitability of alate termite business for household livelihood diversification and food security. The extension agents, nutrition and home-based economics staff would make use of the findings targeting continuous use of alate termites to improve food security situation in Vihiga County. The study also provides basis for further research for holistic expansion of the alate termite value chain.

1.6 Operational Definition of Terms

Attitude	It is one's own unique or special way of viewing things. For this study, all aspects that households attach to consumption of termites.
Capacity	Refers to the ability of an organization, society or an individual to execute all activities to achieve desired objectives or an ability to define and achieve the set goals more effectively. Capacity of farmers could be in terms of willingness to undertake an activity, culture, skills, and knowledge (Morgan, 2006)
Enterprise	For this study, an enterprise is an Income generating entity to diversify sources of income in the household.
Entomophagy	The collection and consumption of insects by human beings as food (Gahukar, 2011).
Food Security	This is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy living (FAO, 2002). The study will focus on income generation for increased for access, food adequacy and availability
Household	A social unit made up of people who live in the same compound, share the same cooking arrangements, and report to the same household head.
Household Food Insecurity	Inability of a household to provide and sustain its members' dietary intake due to a lack of food. There are three components to household food insecurity: Food scarcity, inaccessibility, and underutilization (FAO, 2019).
Livelihood Diversification	The process by which rural families construct a diverse portfolio of activities and social support capabilities in order to survive and to improve their standards of living
Utilization	The act of using something in an effective way. For this study it is conceptualized as promotion of termite usage through commercialization to achieve food security for; income generation, and food adequacy.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Entomophagy

Entomophagy refers to collection and consumption of edible insects by human. It dates to biblical times therefore not a new phenomenon (Backwell & Errico 2001). De Foliart, 1990 described the phenomenon over 10 thousand years ago explaining that insects and other related invertebrates is a source of food all over the planet. This is manifested as recently over 2 billion people in the world practice entomophagy. It has received considerable attention in other parts including Asia and Europe with caterpillars, termites, crickets, and palm weevils being the most consumed insects (Van Huis, 2013). However, Africa is on the lead compared to other continents since its favoured by the existing insect biodiversity (Niassy et al. 2018). Other commonly consumed insects are outlined in Table 1.

The edible species ranges from ants to beetle larvae, eaten by tribes in Africa and Australia as part of their subsistence diets – to the popular, crispy-fried locusts and beetles consumed in Thailand (Pal & Roy 2014). The increase in cases of under nutrition and malnutrition especially in rural communities, prompts the need for alternative nutritional food sources. Therefore, entomophagy could be explored as s tool against food insecurity and malnutrition. Currently, attention is drawn to valuable traditional food resources which is believed to be a more sustainable solution to nutrient deficiency.

Table 1: Percentage of Most Consumed Insects

Order	Example	%	Order	Example	%
Coleoptera	Beetles	3	Isoptera	Termites	3
Lepidoptera	Caterpillars	18	Odonata	Dragonflies	3
Hymenoptera	Bees, wasps, and ants	14	Diptera	Flies	2
Orthoptera	Grasshoppers, locusts, and crickets	13	Others (Dictyoptera, Megaloptera and others)		6
Hemiptera	Cicadas, Leafhoppers, plant hoppers, scale insects and true bags	10			

Source: (Van Huis, 2013)

2.2 Global View of Food Security

Food security is viewed in terms of consistent access to safe, adequate, and nutritious food for an active and healthy life. For a household to be considered food secure, its members must be able to acquire food without resorting to emergency food programs, scavenging as well as other coping strategies (Rosegrant & Cline 2003; FAO, 2009). If a household does not meet these conditions for any time of the year, or if these conditions remain uncertain, it is considered food insecure. The aim of every growing economy is to make its members food secure. However, this will be an issue of global concern for the next 50 years and beyond if appropriate interventions are not put into practice (Rosegrant & Cline 2003).

Therefore, most researchers focus on ways of ensuring food security either through increased production, purchase, or diversification of income (Mc Carthy et al. 2018; Aschemann-Witzel et al. 2019). Critical situation is experienced in trying to meet food demand a time when food production is constrained by climate change. Farmers in Africa more so Sub-Saharan Africa must deal with risks of climate change by diversifying their farming activities (Antwi-Agyei, Stringer, & Dougill, 2014). This will help spread the risk among different crop and livestock and diversification of income. In Kenya, the agricultural sector plays a vital role in ensuring food security, thus policies regarding agricultural enterprises including types of crops and livestock to be produced need to be guided appropriately (GoK, 2017).

2.3 Food Security Situation in Vihiga County

Kenya is among the developing countries that continue to implement strategies and policies on how to make the population food secure. It has made substantive strides in reducing the prevalence of malnutrition, stunting and food insecurity, through several policy interventions which contributed to the fall in the cases of malnutrition from 35% in 2008 to 26% in 2014 (KNBS et al 2015; ICF Macro, 2010). Regardless of the efforts, Kenya continues to experience severe food insecurity (USAID, 2017), challenges persist among the poor households especially among older women, larger households, members with low education levels, and the unemployed. The rise in relative food prices has contributed to the deterioration of food security situation in Kenya (Korir,

Rizov & Ruto 2020). This affects households that rely on small scale agriculture, informal markets and reside in rural areas.

Vihiga county is among the western counties in Kenya, making strides through partnerships to boost food diversity and promote nutrition among households (Oduor et al. 2019). However, population's poorest segments are the still affected by low dietary diversity. The double burden of malnutrition (both undernourished and stunting) is spread across generations from women of reproductive age who become mothers. Recent report shows that 23.5% of children in Vihiga County are stunted (MoH-Kenya, 2015). This points to a missing link between environmental agrobiodiversity and household diet diversification. Therefore, diversification of food resources and promotion of value chain activities of the available food resources would promote employment and contribute to household cushioning techniques against poverty, hunger and promote food security.

2.4 Household Livelihood Promotion and Diversification

Livelihood promotion involves improving the resilience of household livelihoods so that food and other basic needs can be met on a sustainable basis (Emmanuel, 2011). Interventions of this type often aims at reducing the structural vulnerability of livelihood systems, by focusing on improving production to stabilize yields. Livelihood diversification (LD) has also received much attention from researchers with the aim that it would provide pathway to poverty reduction and economic growth in Sub-Saharan Africa (SSA) (World Bank, 2017).

Diversification of rural livelihoods would involve a sectoral shift in rural activities from farm to non-farm activities (Start & Start, 2001). According to Ellis (2000), diversification of individual or household livelihood would mean change in income strategies by increasing the number of activities regardless of the location. Livelihood diversification is believed to promote standards of living however, the subject is still under debate and remains an area of interest in research. Rural livelihood diversification is categorized either by sector (farm/non-farm), function (wage employment or self-employment) or by location (on-farm of off-farm) (Manjur et al. 2014).

According to Timmer (2009) historical lessons from transformation in Europe and North America, has led to an increase in agricultural productivity, as well as industrialization and urbanization, contributing to economic development. However, at micro levels, rural households' participation in farm activities has declined relative to non-farm activities. Thus, with increased infrastructure, better functioning markets, communication coupled with utilization of Non-Timber Forest Products (NTFP) in rural areas there would be rise in income and standards of living.

Sub-Saharan Africa(SSA) has deviated from path to LD due to non-consolidation and sub-division of farms just like in Europe and North America, where farm sizes are becoming smaller (Djurfeldt & Djurfeldt 2013). This has led to decline in farm sizes especially in highly populated areas which has a potential negative impact on rural household welfare and food security in SSA (Muyanga & Jayne, 2014). Low agricultural productivity, coupled with chronic food insecurity and poverty in SSA's smallholder rural economy, results in slow growth toward food security (Alobo, 2015). Therefore, there is need to diversify household sources of income to promote food security and nutrition.

2.5 Harvesting of Termites

In tropical countries most insects are collected from the wild and so alate termites, which are collected during the nuptial flight where the reproductive termites emerge in large numbers from the mounds (Fombong & Kinyuru 2018). Collection of termites is a traditional practice as part of diet and other significance in various countries in Africa. Harvesting techniques vary with the species, termite genus, the region, and the season.

Two categories of methods are used to obtain termites, includes direct collection by breaking termite mounds and the trapping of termites in containers filled with organic matters (Dao et al. 2020). However, they are mostly harvested from the mound by making holes and sending in twigs or sticks to get them out (Malaisse, 2005). Mostly the termite queen termite is the least consumed since they are the most difficult to harvest as it would entail destroying an entire termite mound to locate them(Van Huis, 2017). However, commonly harvested are the soldiers and the alates for either feed, food, or other cultural benefits.

2.6 Overview of Termite utilization

Termite utilization has been part of early hominid, even though, termites are viewed to cause economic damage in farms and houses. At the same time people from various parts of the world utilizes them for feed or food. Backwell & Errico (2001;2008), analysing bone tools in South Africa, concluded that the tools were used by *Australopithecus robustus* to dig into termite mounds, and not, as was supposed earlier, to dig for tubers. Similarly, Desilva & Lesnik (2006) reported that hominids used a combination of soldiers and alates of the genus *Macrotermes* due to their significant amounts of energy-yielding nutrients and potential role as a critical resource for supporting larger-brained hominids.

Studies in central and eastern Africa showed that the fishing technique to extract termites from mounds was the most popular (Backwell & d'Errico 2005). A survey on termite extraction and consumption in Côte d'Ivoire revealed that 97% respondents consumed termites, demonstrating that its part of diet among rural and urban populations (Niaba et al. 2013). Further, the consumption was driven by the nutritional value, flavour, and aroma of these insects, as well as by the curiosity of the people who consume them. Additionally, People living in Nkoya in the northeastern part of the Western Province of Zambia use termites as an important part of their diets (Chavunduka, 1975).

It is noticeable that some species are widely consumed in some countries, suggesting a preference for them, especially those belonging to the genus *Macrotermes*. This predilection is attributed to differences in the nutritional composition of the genus *Macrotermes* since they have high levels of proteins and lipids (Igwe et al. 2011). The genus *mactotermes* is abundant in Africa and are called "big termites", considered one of the favorite foods. They have been historically exploited by humans from a utilitarian perspective coupled with their ecological importance, may contribute to overcome the negative view associated with the winged white termites (Fombong & Kinyuru 2018). In South Africa, the alates of *Macrotermes swaziae* (Full) and *Microhodotermes viator* (Latreille) are considered as edible termite species (Bodenheimer, 2013).

Several termite species are consumed, with *M. bellicosus* being widely eaten in Africa and it constitutes 10% of the total animal biomass in tropics(Van Huis, 2017). Alate termites are popular food in Sub-Saharan Africa, forms part of diets and is enjoyed as a delicacy in most households in the western counties in Kenya, this implies the potential of the genus. Alate termites are the reproductive caste which have a nuptial flight after the first rains following a dry season. The reproductive termites swarm, then shed their wings and are collected depending on the species and time of emergence. Even though abundant termites are only available seasonally especially during rainy and wet season and coincides roughly with the months from April to July (Banjo et al. 2006; Ayieko et al. 2010) and October to December (Ayieko et al. 2010 ; Kinyuru et al. 2013).

However, termites have been utilized for other purposes including treatment of illnesses, they have also been used as potential feed for poultry in many African countries. Particularly smallholder farmers with few scavenging chickens explres ternites as feed (Dao et al. 2020). Additionally, their medicinal properties have been used in treatment of illnesses in various communities.

2.6.1 Nutritional Value of Termites

Termites' central role as an edible insect in Africa owes the prestigious status to its rich fat and protein (Ekpo, 2009). The alate termites contain high quality nutrients, especially digestible proteins as well as fats that are more bioavailable than minerals from plant foods (Omotoso, 2006). Significant proportions of nutrients have been documented especially of the *Macrotermes* which contain significant proportion of macro and micronutrients.

Termites reportedly contain 44.82–47.31 g/100 g of fat, protein 33.51–39.74 g/100 g, carbohydrate 0.72–8.73 g/100 g, iron 53.33–115.97 mg/100 g and zinc 7.10–12.86 mg/100 g while amount of unsaturated fat ranges from 50.54–67.83% (Kinyuru et al. 2013). Termites form part of human diet providing useful nutrients particularly for those suffering from malnutrition due to low protein in their diets. This therefore makes termites a great deal for curbing nutritional deficiency in various regions. this

study uses the nutritional provisions to anchor on potential of alate termites to provide household dietary requirements.

2.6.2 Attitude towards Termite Utilization

The willingness to consume termites has been surveyed in the United States of America and India based on 'attitudes toward food'. A substantial proportion of both Americans (72%) and Indians (74%) were at least willing to consider eating some form of insect food (Ruby, Rozin & Chan 2015). Disgust seems to be the most common reaction of respondents at the prospect of eating insects. Likewise, Iannuzzi, Sisto & Nigro (2019), reported that consumption of termite-based products is more on consumers' reactions to novel food based on cultural bias rather than on 'neophobia in itself'.

A study on influence of food neophobia and socio-cultural factors on the consumption and consumers' willingness to consume three edible insects in Uganda reported that culture and familiarity with edible insects are important determinants (Olum et al. 2021). More importantly individual characteristics determine willingness to consume the termites. In Kenya, consumption of termites is mostly practiced in western Kenya especially in Kakamega, Bungoma and Vihiga county. Several species of termites are reportedly consumed even though, winged termites of the genus *Macrotermes* are commonly preferred in various recipes (Van Huis, 2003). Therefore, improving knowledge of consumers about edible insects and their nutritional potential is key in dealing with neophobia.

2.6.3 Utilization of alate Termites for Livelihood Promotion

Households in developing countries drive bulk of their income from single source without diversification hence posing financial risks (Frank & Enkawa 2008). However, diversification into non-farm income sources is growing overtime and accounts for considerable share of household income. Insects are a source of NTFP with greater benefits and a relatively low investment cost. Insect harvesting/rearing is a low-tech, low-capital investment option that offers entry even to the poorest sections of society. Mini livestock offer livelihood opportunities for both urban and rural people even

though insect rearing can be low-tech or very sophisticated, depending on the level of investment.

Therefore, diversification into insect collection and utilization besides crops, can create an alternative income-generating activity as a coping strategy that is economically and environmentally sustainable (Ellis, 2000). Interventions to ensure linkages between surplus periods and off seasons could also be strengthened through investment in value chain activities, value addition and market organization. Such interventions could help improve the terms of trade for the poor by improving local access to income, enhancing food access through economic empowerment.

However, this could be altered by diversification into entomophagy as an enterprise to promote non-farm business by harvesting and marketing of insects such as the alate termites which would serve as a basis for economic exchange as well as domestication of other insect species. For instance, Mopane Worm are widely marketed and eaten across the Southern Africa and is no longer food for the rural but a source of livelihood diversification (Payne, 2020).

Research has been done on the ability of edible insects to contribute to livelihoods, for instance harvesting the Mopane caterpillar *Imbrasia belina* (Lepidoptera: Saturniidae) in Southern Africa is an 85 million US$ business, mainly carried out by women (Ghazoul, 2006; Van Huis, 2016), the marketing of the Edible stinkbug *Encosternum delegorguei* (Hemiptera: Tessaratomidae) in sub-Saharan African countries mainly benefits women in impoverished rural communities (Dzerefos & Witkowski, 2015), edible pupae of a saturniid wild silkworm, is commercially reared for sericulture in Madagascar, contributing to poverty alleviation. Likewise, weaver ant larvae and pupae sell for about US$12 per kg in Laos and their sale can account for up to 30% of annual household income in rural Thailand. Grasshoppers in Mexico sell for US$13 per kg, and wasp nests, a rare treat, sell for US$100 per kg in Japan (Payne, 2015).

To promote utilization, there is need to venture in marketing, maintaining traditional knowledge on insect processing as well as improve on means of preservation to ensure year round supply of termites and other insects (Van Huis, 2003). Additionally, there

could be diversification of products through provision of tastier products as well as communication of information on nutritional and economic value. In countries like Zimbabwe, South Africa Zambia and Nigeria, households make a good living from selling termites and other insects (Ghazoul, 2006). They are not only source of nutrition but a source of income for economically marginal rural population. Alate termite commercialization reportedly promotes income levels among households as the value chain shifts from subsistence to commercial (Kiasaka, 2018).

2.7 Theoretical and Conceptual Framework

2.7.1 Theoretical Framework

The study adopts two theories, that is Neo-Malthusian Perspective (Mellos, 1988). and the Social Learning theory (Bandura & Walters,1977; Bandura, 1985) in trying to explain the aspects of food security and adoption of emerging practices of which use of insects for food security aspects and livelihood forms basis of the study.

1. **Neo-Malthusian Perspective (NMP)**

Food security debate is an integrated assessment and often begins with ecological concerns of population congestion and the ability of the earth to feed the planet, warning of scenarios from unchecked population growth and consumption of earth's resources. The theory holds that, food security can be maintained only through achieving sustainable society that meets the needs of the human population, without compromising abilities of the future generation. Thus, balancing human need for food and earths abilities is key for sustainability.

Agricultural practices must therefore utilize strategies to ensure food security with minimal unrecoverable environmental damage with enough output for markets and consumption. The research therefore holds on this theory in trying to explain aspects of food security and need of termite utilization which is a reliable entity in terms of environmental protection, food security as well as livelihood promotion among households.

2. Social Learning Theory (SLT)

The theory is an essential component of sustainable natural resource management and promotion of desirable behavioral change (Muro & Jeffrey 2008). SLT holds on the idea that people learn from interactions with others in a social context; by observing others behavior one develops a similar behavior, assimilates, and then imitates certain aspects. The study thus holds on the theory to explain on how indigenous knowledge on harvesting (collection), preparation and preservation of alate termites within the social context of the society, this enhances passage and preservation of this information from generation to promote utilization of the termites as one of the sustainable food security and livelihood entry points.

According to Bandura & Walters (1977), imitation involves actual reproduction of observed motor activities and is rooted in traditional learning theory (TLT). The proponent believes that reinforcement could not account for all learning and change in behavior thus he added as asocial element that people adopt new technologies, information, and behavior by watching other people thus is founded on principals of observation, imitation, and modeling. Thus, includes both education and training received on termite utilization.

2.7.2 Conceptual Framework

Consumption of termites is believed to contribute to household food security as well as household livelihood diversification either directly or indirectly through availability, access, collection, and utilization. Including termites in the household diet could be potential in improving dietary options in the household, that is direct contribution to food security. On the other hand, income generated from marketing of alate termites and other products would be used to secure other household requirements which is an indirect contribution to food security through access, availability, and utilization.

The independent variables include capacity of households, Termite collection, marketing, and utilization, which is presumed to influence household food security (Dependent Variable). The variables are influenced by intervening variable, which are the prevailing environmental conditions like rainfall. Termite availability for collection is always seasonal and become abundant at the onset of the rains.

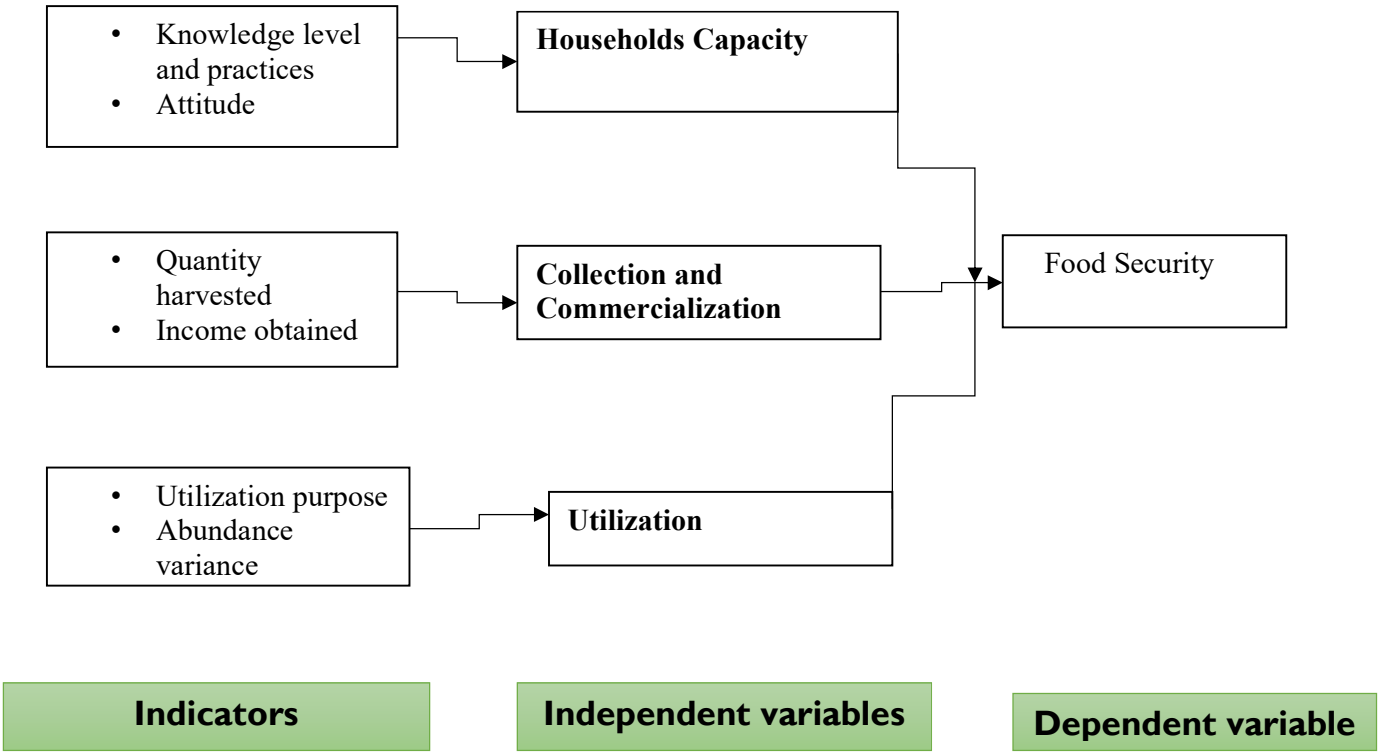

Figure 1: Conceptual Framework.

Source: Author

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

This chapter gives information on methods used in the study including the research design, description of the study area, target population, sample size determination, sampling procedure, measurement of variables, research instruments, data collection procedures, ethical considerations, and data analysis.

3.2 Description of the Study Area

The research was carried out in two sub-counties of Vihiga county in Western Kenya, that is Luanda and Hamisi. The county was selected due to the concentration of households involved in collection, marketing, and utilization of alate termites, as well as the emergence of termite marketing. According to Government of Kenya report (2013), majority of farmers in the study area practice small scale crop and livestock production which is reliant on annual rains that makes the area susceptible to food insecurity. Other economic activities include small scale fish farming. The climatic condition is Tropical and the county experiences several wet weather occurrences. Luanda sub county has a total population of 105,707 with26,766 households and forms one of the largest known markets for termite commercialization while Hamisi sub county has a population of 159,070 representing 37,982 rural households (KNBS, 2019). The average household size in Luand and Hamisi Sub-County were 3.9 and 4.2 respectively.

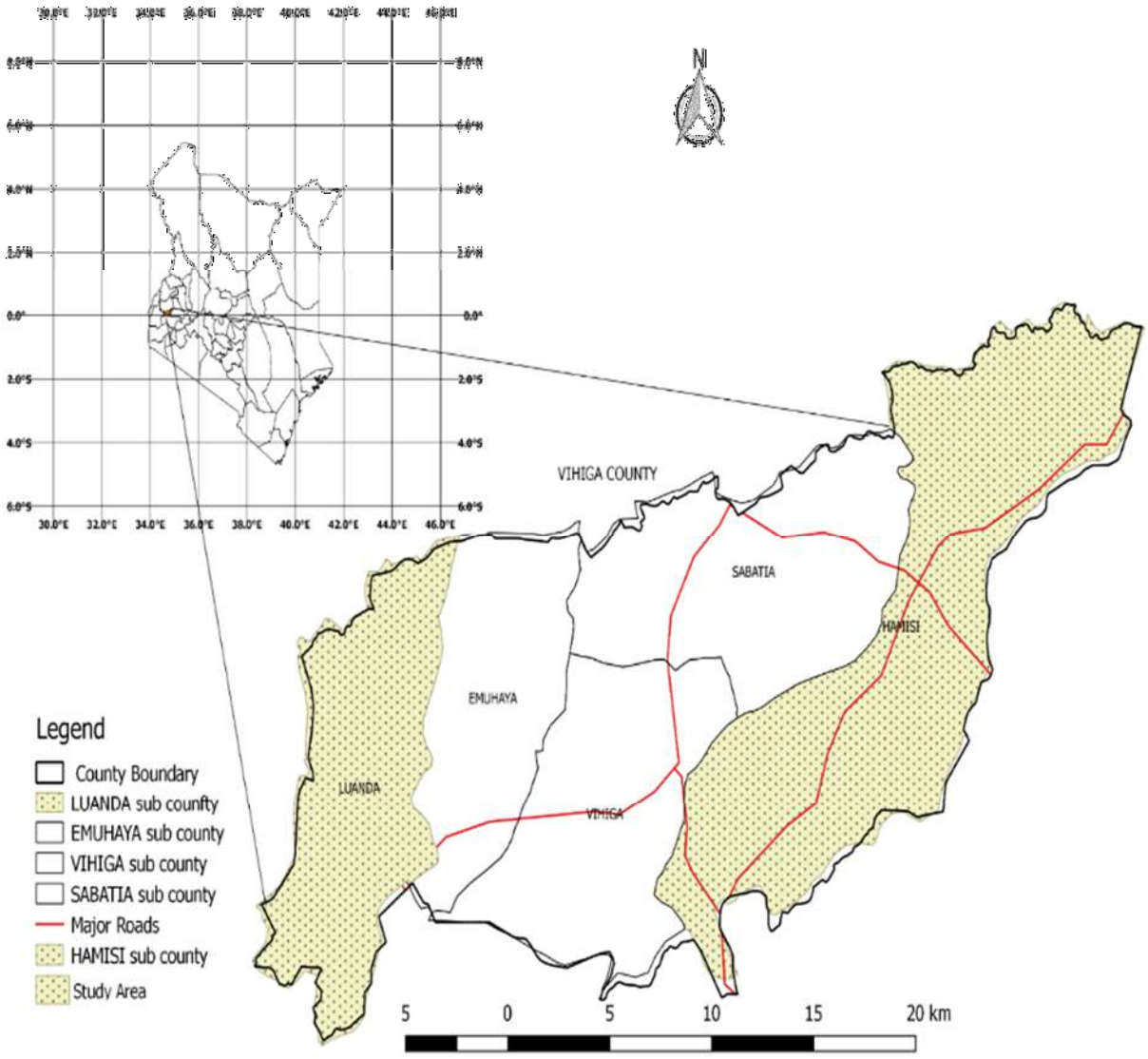

Figure 2: Map of the Study Area

Source: KNBS

3.3 Research Design

The study employed cross-sectional survey design to describe the potential of termite collection and utilization on household food security by explaining the relationship between the variables in the study to compare groups where data was collected. The design enables a researcher to investigate and describe the existing status of behaviour or a phenomenon and allows the use of a structured questionnaire as research instrument (Mugenda &Mugenda 2003; Olsen & George 2004).

3.4 Target Population

The target population consisted of households in Vihiga County, that provided a sampling frame from which a proportionate sample was drawn through a random sampling technique. The respondents were within all age groups preferably household heads involved in harvesting, marketing, and utilization of alate termites.

3.5 Sampling Procedure

The study employed multistage sampling procedure where for the first and second stage, purposive sampling was used to select Vihiga county and the two sub-counties (Luanda and Hamisi). Luanda Sub-County represented peri-urban households while Hamisi Sub-County represented rural households. In the third stage, stratified proportionate sampling was then used to get the appropriate sample size per stratum and finally Simple random sampling was employed to select a sample of households within the study area Kothari (2004). The two sub-counties were treated as stratum and proportionate samples obtained to ensure each subgroup gets appropriate representation.

3.6 Sample Size Determination

The required sample was computed using the Slovins (1960) sample size determination formula for a known population. With a known population of 64,752 households within Luanda and Hamisi sub-counties of Vihiga County (KNBS, 2019), the sample size was computed using the formula:

$n = \frac{N}{1+N(e)^2}$ ……(i)

where;

n-is the sample size

N -is the population size (64,752 the population of Luanda and Hamisi Sub-Counties)

e- the level of significance.

An error margin of 7% that would give the desired sample size was considered.

$$n = \frac{64752}{1 + 64752(0.07)^2} = 204$$

Kothari's formula for proportionate sampling will be used to obtain appropriate samples from the two strata. This is computed as follows:

$n_1 = n * \frac{N_1}{N}$ ……(ii)

$n_2 = n * \frac{N_2}{N}$ ……...(iii)

Where;

n_1 and n_2 are the sample sizes drawn from the first and second strata (Hamisi and Luanda sub county) respectively whereas;

N_1 and N_2 are the corresponding household population sizes of Hamisi and Luanda sub county respectively

The sample size drawn from Hamisi sub-county will be:

$n_1 = 204 * \frac{37,982}{64,752} = 120$ and

The sample size drawn from Luanda sub-county will be:

$n_2 = 204 * \frac{26,766}{64,752} = 84$

Table 2*:* Distribution of sample per the sub-counties

County	Sub-county	Household population	Total sample	Proportionate samples.
Vihiga	Hamisi	37,982	$n = \frac{64752}{1+64752(0.07)^2} =$ 204	120
	Luanda	26,766		84

3.7 Research Instrument

The study employed a semi-structured questionnaire due to its relevance and ease to administer. The questionnaire was semi-structured in a manner it could address the objectives of the study and to address the research questions in place. The questionnaire had four sections with questions arrayed on Likert scale with some open ended. Section A had question on demographic characteristics of the respondents while section B, C and D has questions on attitude and knowledge, relating to harvesting, Marketing, and consumption/utilization. This gave an insight on the utilization of a late termites for household food security and income diversification.

3.8 Pre-testing of the Research Instrument

piloting study was done to assess the validity and reliability of the instrument in randomly selected households. This gave room for comments and suggestions concerning the instrument clarity and consistency to address the research objectives. Following the responses, adjustments were made on the questionnaire to ensure questions do not elicit unintended responses. In social sciences, a sample size of 10-20% is generally acceptable for a pilot study (Hazzi & Maldaon 2015). Therefore, the researcher used 15% of the total sample size to get 30 samples for pretesting. The pre-test was conducted in Tharaka Nithi county, having similar ecological conditions as the study area with spreading entomophagy.

3.9 Reliability of the Instrument

The degree of consistency of data is obtained using a given instrument. The reliability coefficient of the instruments was calculated using Cronbach's Alpha Coefficient followed by calculation of total variance, individual variances, and then the sum of individual variances. The Cronbach's Alpha Coefficient threshold for internal consistency was to be between 0.68 – 0.84.

3.10 Validity of the Instrument

The extent of accuracy of the data and validity was verified. This was done by the supervisors who cross-checked the questionnaire to monitor whether the instrument is detailed enough to capture the research objectives and simple to be relevant to all respondent categories.

3.11 Data Collection Procedure

Data was collected through face-to-face interviews using semi-structured questionnaire from selected household heads involve in harvesting, marketing, and consumption. The questionnaire was administered in the two sub-counties within Vihiga county to obtain information pertaining collection and utilization of the alate termites. Probing questions were employed to get elaborate information on the process of harvesting and how termite utilization contributes to household food security as well as household' income.

The researcher worked closely with relevant authorities including the chiefs, and sub-county extension staff to gain access to the community and urban centres where necessary data were obtained. Enumerators were drilled on how to use Open Data Kit (ODK) for data collection. They were residents of the sub-counties that would ensure use of local dialect to gather more information from the aged respondent category.

3.12 Ethical Considerations

The researcher sought for official approval from the Ethical Review Committee, Postgraduate school and NACOSTI (Ref No: 315851) to enhance confidentiality of the respondents and assure quality of the research. This began by clearly communicating the intention of the research which was mainly Academic. Interviews being the main means of data collection there was need to have permission from the area leaders who introduced the researcher to key players. The local leaders in turn promoted awareness of the study to build trust for the respondents to consent for the interview.

3.13 Data Analysis Procedure

The raw data collected using an online platform, were assembled, grouped into categories, coded, and entered in MS Excel sheet. Qualitative data was analysed through thematic content analysis. This involves assembling converging ideas and organizing them into distinct categories, patterns, and themes, aligned to the study objectives. The themes were reported as Harvesting that included three codes; (harvesting techniques, specie identification, time of harvesting) and constrains to alate termite marketing (perishability, seasonality, and over-exploitation). Other analyses were done using R version 4.0.2 (RCore Team, 2020) and Statistical Package of Social Science (IBM SPSS V25).

3.13.1 Households' Capacity for Termite Collection and Utilization in the Community

The key indicators of households' capacity for collection and utilization of termites were attitude, knowledge and practices pertaining to willingness to consume, preference of alate termite preparation form, awareness of utilization purposes and harvesting. These indicators were measured on a five-point Likert scale (with 5 being strongly agree). The respondents were asked to indicate the extent of their agreement on each statement (indicator). i.e., willingness to consume, preference of various preparation forms, categories of utilization purposes.

Descriptive statistics such as frequencies, percentages and charts were then used to summarize the data. Furthermore, Chi Square statistic was then employed to determine the association between the indicator variables and the sociodemographic variables (e.g. age, gender, education level, occupation, marital status).

3.13.2 Termite Collection and Marketing to Household Income for Improved Household Livelihood

Composite variable (appendix 5) of the five-point Likert scale which was computed and in turn used further in the analysis. The Chi-square was then used to test how collection and marketing of alate termites is associated to supply benefits of alate termite, test how socio-economic factors influence participation in alate termite business. Moreover, multivariable regression model was used to assess how termite commercialization contribute to improved household livelihoods were used for inference. The model specification is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon_{ij} \quad \text{.....(iv)}$$

$where$:

Y = is the dependent variable: supply_benefits of alate termites**, (**a composite variable created from the average of commercialization, sufficient supply, and utilization for improved livelihoods. The indicators were treated as Purch1, Purch2 and Purch3 respectively, summated and averages generated)

X_{is}= is the set of independent variables (utilization purpose, quantity sold and income obtained); i = 1, 2…,n (Table 3)

$\beta_0 -$ is the intercept, the value of Y without any significant effect of X's

$\beta_1, \beta_2, \dots, \beta_n -$ are slope parameters to be estimated that show the change in Y with a corresponding change in X's.

$\varepsilon_{ij} -$ the random variations/error term

To determine the net profit Gross Margin Analysis as a popular model was employed. Input-output data from the different marketers were used to compute gross margins. Gross margin is the value of the output of an individual enterprise (gross value of a business), less the variable costs directly attributable to generating the value (Salako et al. 2013). The gross margin relationship is stated as follows:

$$\mathrm{GM} = \mathrm{TR} - \mathrm{TVC} \quad \dots\dots(v)$$

$$\text{Profit} = \text{TR-TC} \quad \dots\dots(vi)$$

$$\text{TC=TFC+TVC} \quad \dots\dots(vii)$$

Where:

GM = Gross Margin

TVC = Total variable costs

TFC = Total Fixed Cost

TR = Total Revenue

3.13.3 Contribution of Alate Termite Collection, Marketing and Utilization to Household Food Security in Vihiga County

Chi-square tests for independence were used to assess whether alate termite availability, access, affordability, sustainability, and adequacy are associated with socio-economic characteristics. Furthermore, multivariable regression model to assess the influence of utilization purpose, abundance variance, quantity sold, and income generated influence food security index.

The model was specified as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n + \varepsilon_{ij} \quad \dots\dots(viii)$$

$where$:

Y = is the dependent variable (Food security index**,** a composite variable created from the average of availability, access, affordability, sustainability, and adequacy) (Appendix 5)

X_{is}= is the set of independent variables (utilization purpose, consumption patterns, termite abundance variance, quantity sold, and income obtained)

$\beta_0 -$ is the intercept, the value of Y without any significant effect of X's

$\beta_1, \beta_2, \ldots, \beta_n -$ are slope parameters to be estimated that show the change in Y with a corresponding change in X's.

$\varepsilon_{ij} -$ the random variations/error term

Table 3:Definition of variables used in regression model

Variable	**Definition**	**Measurement**
X_1 =Utilization_purpose	Purposes of alate termite utilization	Ordinal
X_2=Quantity_sold	Quantity of alate termites	Continuous
X_3=Income_obtained	Amount of income from selling alate termites	Continuous
X_4=Consumption_pattern	Reasons for consumption of alates.	Ordinal
X_5=Abundance_variance	Factors influencing abundance over time	Ordinal

Assumption of the models

i. The error term is normally distributed thus selection of the model
ii. There is no multicollinearity tested using the variance inflation factors, which were below <5 therefore appropriateness of the model.
iii. The residuals are normally distributed.

CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the findings and the discussion including the demographic characteristics of the households, household capacity for collection and utilization of alate termites, marketing of alate termites for household income and livelihood diversification and contribution of alate termites to household food security status.

4.2 Results

4.2.1 Descriptive Statistics

The age of respondents ranged from 12 to over 65 years, the majority were within the age of 25-44 (41.2%) while the least were those below 14 years (2.5%). 60.3% of respondents were female and 40% males. A significant proportion (about 93%) of the respondents were formally educated. In Luanda sub-county, majority of the respondents (45.2%) had attained secondary level education compared to 31.7% in Hamisi sub-county. Out of the interviewed population 40.0% relied solely on farming as the main source of livelihood in both the sub-counties with others relying on casual jobs. 59.3% of the respondents were married as indicated in Table 4 below.

Table 4:Socio-demographic Descriptive Statistics

Variable	Total (%)	Luanda (N = 84), Freq (%)	Hamisi (N = 120), Freq (%)
Gender			
Male	81 (39.7%)	40 (47.6%)	41 (34.2%)
Female	123 (60.3%)	44 (52.4%)	79 (65.8%)
Age			
1 – 14	5 (2.5%)	4 (4.8%)	1 (0.8%)
15 – 24	37 (18.1%)	25 (29.8%)	12 (10%)
25 – 44	84 (41.2%)	30 (35.7%)	54 (45.0%)
45 – 65	63 (30.9%)	20 (23.8%)	43 (35.8%)
Above 65	15 (7.7%)	5 (6.0%)	10 (8.3%)
Marital status			
Married	121 (59.3%)	41 (48.8%)	80 (66.7%)
Single	49 (24.0%)	30 (35.7%)	19 (15.8)
Divorced	4 (2.0%)	2 (2.4%)	2 (1.7%)
Widow	30 (14.7%)	11 (13.1%)	19 (15.8%)

Education Level			
Primary	61 (29.9%)	22 (26.2%)	39 (32.5%)
Secondary	76 (37.3%)	38 (45.2%)	38 (31.7%)
Tertiary	54 (26.5%)	17 (20.2%)	37 (30.8%)
None	13 (6.4%)	7 (8.3%)	6 (5.0%)
Occupation			
Educationist	26 (12.7%)	17 (20.2%)	9 (7.5%)
Farmer	78 (38.2%)	30 (35.7%)	48 (40.0%)
Casual Labourer	36 (17.6%)	16 (19.0%)	20 (16.7%)
Other	64 (31.4%)	21 (25.0%)	43 (35.8%)

4.2.2 Households Capacity

4.2.2.1 Consumption of Alate Termites

Households' capacity was assessed in terms of, attitude, knowledge, and practice. pertaining to willingness to consume, preference of alate termite preparation forms, utilization purposes and harvesting. There was an inclusion criterion of which preferably only respondents that participated in either consumption (81%), harvesting (31%) and commercialization (50%) of alate termites were interviewed (Table 5).

Table 5: Summary of rate of Respondents Involvement in Alate termite collection, consumption, and marketing.

Parameter	Variable	Frequency	Percentages
Harvesting of alate termites	Yes	64	31%
Consumption of alate termites	Yes	164	81%
Marketing of alate termites	Yes	32	50%

Chi-square test of association on the categorical variables and socio-economic characteristics (Table 6). Consumption of blanched was significantly associated with the occupation of the respondent. Eating raw termites was significantly associated with the educational status of the household head.

Table 6:Association between selected demographic variables and forms of alate termites' preparation.

Variable	Fried		Blanched		Sundried		Raw	
	Freq	p-value	Freq	p-value	Freq	p-value	Freq	p-value
Occupation								
Farmer	67		33		65		55	
Educationist	31	0.421	7	0.023*	20	0.772	18	0.712
Casual labourer	29		16		28		24	
Other	48		36		48		39	
Education								
Non-formal	12		6		13		10	
Primary	54	0.082	34	0.111	52	0.651	49	0.029*
Secondary	58		28		57		48	
Tertiary	41		24		39		29	
Marital status								
Married	104		62		102		82	
Single	34	0.065	17	0.018*	32	0.036*	28	0.05*
Divorced	3		1		2		3	
Widow/er	24		12		25		23	

*Note * shows the level of significance at 95% confidence level*

χ2- Was used to determine the relationship between the categorical demographic variables and consumers preferred forms of alate termite preparation.

4.2.2.2 Purposes of Alate Termite Utilization

Alate termite utilization purposes were determined by considering respondents' level of agreement on the varied options of utilization. The alates were used for various purposes including as food supplements, health purposes, income, and feed (Figure 3). Women were mainly involved in feeding alates to chicken since they are easily available and nutritious. Smallholder farmers with scavenging chich also fed alate termites to their chicken.

Test of association (Table 7) revealed that educational attainment was statistically significantly associated with using alate termites for feeding chicken and due to poverty. The current occupation status was significantly associated with the use of alate termites for health benefits, chicken feeding and poverty.

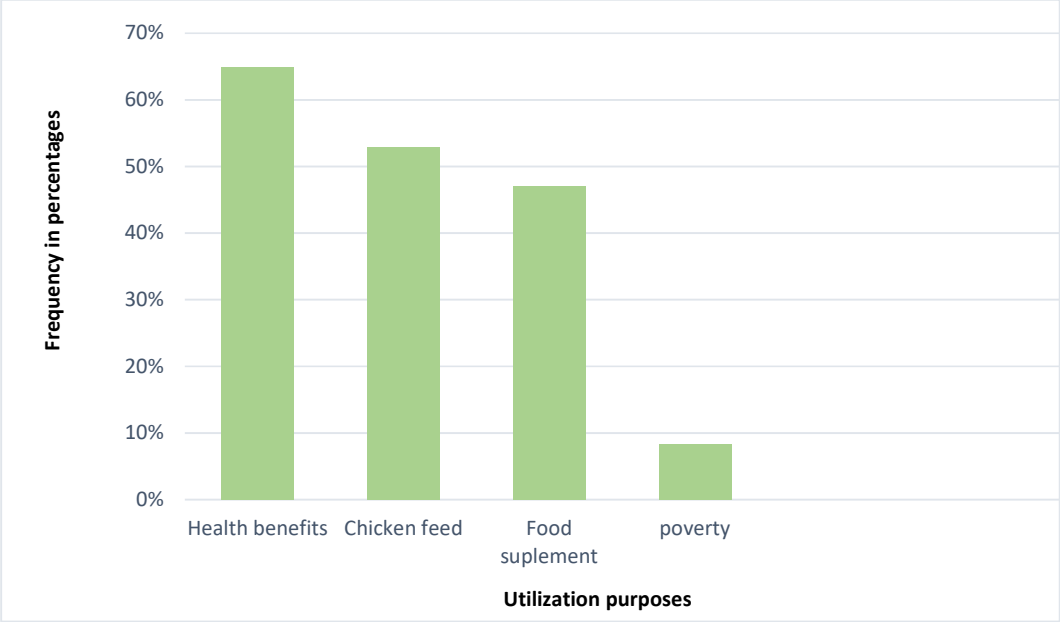

Figure 3:Percentage of utilization purposes

Table 7:Association between alate termite utilization purposes and selected demographic variables

Variable	Health benefits 65%)		Chicken Feed (53%)		Poverty due to low income	
	Freq	**p-value**	**Freq**	**p – value**	**Freq**	**p – value**
Education						
Non-formal	11		8		2	
Primary	40		38		6	
Secondary	33	0.061	36	**0.0004***	4	**0.026***
Tertiary	25		22		3	
Gender						
Male	37	0.353	40	0.668	6	0.213
Female	72		64		8	
Occupation						
Farmer	53		47		6	
Educationist	10		14		0	
Casual laborer	17	**0.037***	14	**0.019***	6	**0.002***
Other	29		29		6	

*Note * shows the level of significance at 95% confidence level*

4.2.2.3 Knowledge and Practices on Alate Termite Harvesting

This was assessed using respondents' knowledge level on methods of harvesting, specie identification and time of harvesting. The study revealed that 30% of the respondent's harvest alate termites, females of various age categories were greatly involved. Harvesting time of harvesting was mainly at the onset of long rain season between March to June. Indigenous knowledge, size of the termite and the type of wings were used to identify species being harvested. It was observed that harvesting methods varied with specie to be harvested. Methods used were use of light and other illumination to attract the alate termites, water traps, hand picking directly from the mounds. Variation in termite abundance was influenced by seasons (39.6%), type of soil (36.7%) in each area_and continuous use of pesticide and other agro chemicals (23.7%). Other contributing factors were Mound ownership and distance covered to the harvesting sites these determined the quantity harvested by a given household. Averagely harvesters covered 6-10Km to harvest.

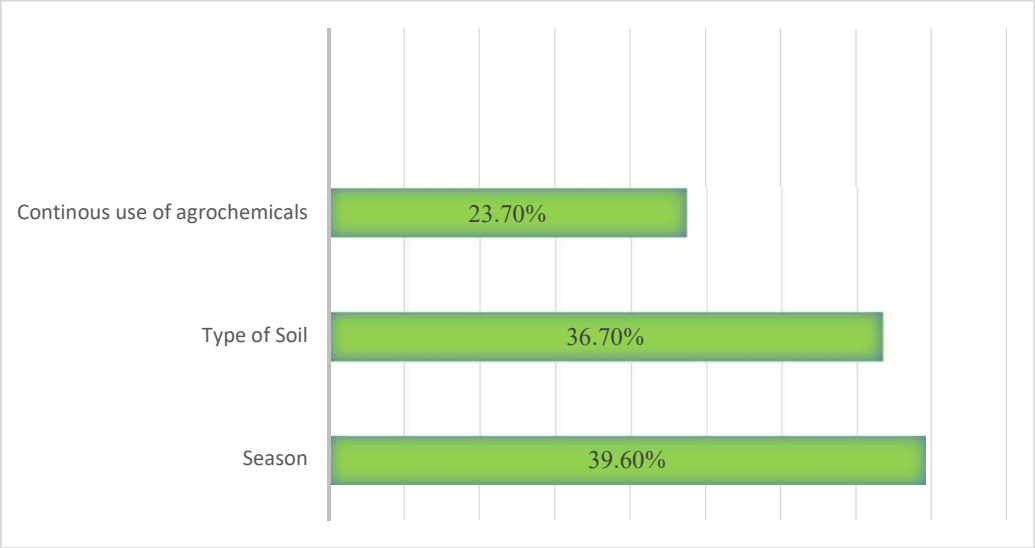

Figure 4: Factors influencing Abundance of late Termites.

Analysis revealed that educational status of the household head was significantly associated with the influence of soil type, season, and the use of agrochemicals on termite availability (Figure 4). Awareness of termite availability by occupation was significantly associated with the soil type and the use of agrochemicals. Awareness of termite availability regarding season was significantly associated with gender (Table 8).

Table 8:Association between alate termite abundance variance and selected demographic variables

Variable	Type of soil		Season		Agrochemicals	
	Freq	p-value	Freq	p-value	Freq	p-value
Occupation						
Farmer	40		49		19	
Educationist	19		21		15	
Casual laborer	22	**0.025***	25	0.482	15	**0.047***
Other	47		44		33	
Education						
Non-formal	4		8		2	
Primary	35		35		24	
Secondary	46	**0.004***	56	**0.034***	31	**0.009***
Tertiary	44		40		32	
Gender						
Male	50	0.234	53	**0.002***	32	0.280
Female	79		86		51	

*Note * shows the level of significance at 95% confidence level*

4.2.3 Collection and Commercialization of Alate Termites

4.2.3.1 Marketing of Alate Termites

Half of the harvesters (50%) took part in alate termite commercialization out of which (34%) had been in the alate termite business for about 3-5 years, some 6-10 (28.1%) years. This is significantly associated to Education (p=0.026) and occupation (p=0.014) of the respondent. Women dominate the termite business and marketing was due to high quantities of supply during rainy seasons and market availability. Sold in open markets in rented kiosks (48%) or hawked in open air (49%). Contribution of alate termites to household livelihood was reportedly determined by quantity harvested and sold, relative price, amount of income obtained. Alate commercialization contributes 9% to total household income (Table 9).

4.2.3.2 Profitability of Alate Termite Enterprise

This was calculated in form of gross profit from various marketers in the rented kiosks and the (GM) is given by the equation using the variable costs and receipts in Table 9. I.e., Quantity harvested by the cost of alate termite sold (Kg), Expenses: transportation

cost: distance to the market by the cost of transportation as shown, municipal charges and kiosks rent

Table 9: Input-output data for gross margin computation

Quantity harvested per month	Pricing of alates	Average transportation cost/Km	Municipal costs Ksh/day	Average Rent/month
1-50Kg (25%) 51–100 kg (75%)	1 tablespoon @ sh. 5 250gms @ sh. 30 500gms @ sh. 100 1 kg @ sh. 400 - 600 2 kg @ sh.800 – 1000	Motorcycle @ sh. 100 Public service @ sh. 200 Bicycle @ sh. 50	Kiosks@100 Open market @50	Kiosks @3,500

Variable cost: Transportation, =2,500

municipal charges=100*4=400

Fixed Cost: Rent-=3,500

Total Cost= (2,500+400) + 1,500=6,400

TR= (50.33kgs*Ksh500) =25,165

$GP = 25{,}165 - 6{,}400$

GP =Ksh 18, 765 per month

Gross profit margin- shows the percentage of revenue that exceeds costs of goods sold.

$$\text{Gross Profit Margin} = \frac{Revenue - Cost\ of\ Goods\ Sold}{Revenue}$$

$$\frac{18{,}765}{25{,}165} \times 100$$

$$= 74.1\%$$

Multivariable regression revealed potential influence of abundance variance on the benefits derived from alate commercialization (Table 10).

Table 10: Summary of the Estimates of the Regression Parameters

Regression coefficients					Multicollinearity	
	B	**Std. Error**	**t-value**	**p-value**	**Tolerance**	**VIF**
Constant	1.035	0.594	1.744	0.093		
Utilization purpose	0.755	0.233	3.242	0.003*	0.462	2.163
Quantity sold per season	-0.478	0.247	-1.933	0.064	0.770	1.299
Income per season	0.301	0.276	1.091	0.285	0.428	2.336

*Note * shows the level of significance at 95% confidence level*

- $\boldsymbol{i.e.\ Supply\ benefits = f(utilization\ purpose + quantinty + income)}$
- *The coefficient for utilization purpose was 0.755, (statistically significant) meaning that for a one unit increase in utilization purpose we would expect a 0.755-unit increase in supply Benefits.*
- *The coefficient for quantity was -0.478, meaning that for a one unit increase in quantity we would expect a 0.478-unit decrease in supply benefits.*
- *The coefficient for utilization purpose was 0.301, meaning that for a one unit increase in income would expect a 0.301-unit increase in supply benefits.*
- *A Variance Inflation Factor of 2.163, 1,299, 2.336 were realized which is within acceptable range.*

4.2.4 Contributions of Alate Termites to Household Food Security

Role of alate termites in promoting household food security was reportedly dependent on their availability, access, sustainability, adequacy, and nutritional potential. In terms of Nutrition the contribution was notably high (64.7%), followed by affordability. Compared to availability and access which were low as shown in Table 11 below.

Table 11: Measure of Utilization of alate Termites using Food Security Indicators

Indicators	Not at all	Very low	Low	High	Very high
	Freq (%)	Freq (%)	Freq (%)	Freq (%)	Freq (%)
Availability	2 (1.0)	52 (26.9)	131 (67.9)	8 (4.1)	0 (0.0)
Access	5 (2.6)	56 (29.0)	127 (65.8)	5 (2.6)	0 (0.0)
Affordability	5 (2.6)	31 (16.1)	123 (63.7)	**9 (4.7)**	**25 (13.0)**
Sustainability	5 (2.6)	41 (21.2)	142 (73.6)	5 (2.6)	0 (0.0)
Adequacy	5 (2.6)	34 (17.6)	144 (74.6)	10 (5.2)	0 (0.0)
Nutrition	2 (1.0)	28 (14.5)	31 (16.1)	**58 (30.1)**	**74 (38.3)**

The analysis revealed that education attainment was significantly associated with availability, access, affordability, sustainability, adequacy, and nutrition. Occupation was significantly associated with affordability (Table 12). Further confirmed by a multivariable analysis, that showed abundance variance significantly (p=0.045) impacts household food security index (Table 13).

Table 12: Association between selected demographic characteristics and extent of termite utilization for food security

Variable	Education			Occupation		
	X^2	p-value	Df	X^2	p-value	df
Availability	36.55	0.0002*	12	25.76	0.011	12
Access	29.21	0.003*	12	-	-	-
Affordability	32.89	0.004*	15	33.09	0.004	15
Sustainability	26.14	0.010*	12	-	-	-
Adequacy	26.72	0.008*	12	-	-	-
Nutrition	27.42	0.025*	15	29.86	0.012	15

*Note * shows the level of significance at 95% confidence level*

Table 13: The influence of termite utilization purpose, abundance variance, quantity sold, and income generated on food security

Regression coefficients					Collinearity statistics	
	B	**Std. Error**	**t-value**	**Sig.**	**Tolerance**	**VIF**
Constant	2.565	0.605	4.240	0.000*		
purpose_utilization	0.288	0.152	1.890	0.071	0.283	3.536
abundance_variance	0.190	0.090	-2.114	0.045*	0.396	2.526
quantity sold per season	-0.214	0.160	-1.344	0.191	0.516	1.936
income per season	0.205	0.155	1.318	0.200	0.360	2.774
consumption_reason	0.098	0.158	.617	0.543	0.536	1.866

*Note * shows the level of significance at 95% confidence level*

$Foodsecurity$=2.565+0.288($utilizationpurpose$)+0.190($abundance$)−0.214($quantity$)+0.205($income$)+0.098($consumption$)

- *The coefficient for utilization purpose was 0.288, meaning that for a one unit increase in supply benefits we would expect a 0.288-unit increase in supply.*
- *The coefficient for abundance variance was **0.190, (statistically significant)** meaning that for a one unit increase in alate termite abundance we would expect a 0.190-unit increase in food security.*
- *The coefficient for income per season was 0.205, meaning that for a one unit increase in food security we would expect a 0.205-unit increase in food security.*

4.3 Discussions

4.3.1 Households' capacity for Collection and Utilization of alate Termites

4.3.1.1 Consumption of Alate Termites

A whopping 81% of the respondents willingly consume alate termites (Table 5) attributing to the higher rate of collection and marketing in Vihiga County. Consumption pattern was influenced by individuals' preference of various preparation forms (blanched, sundried, fried, raw) and awareness of potential benefits (feed or food). Consumption of alate termites was reportedly higher among respondents of all age categories and gender, this is in consonance with the findings of Nyeko & Olubayo (2005) that both male and female of all ages consume soldiers, alates and workers in Uganda. Generally, consumption depends upon insect palatability, taste, nutritional value. However, no ethnic restrictions to consumption were reported as per Sere et al. (2018).

Chi-square test of association on the categorical variables and socio-economic characteristics (Table 6) revealed a statistical significance between eating raw termites and the educational status (p-value=0.029) and marital status (p-value=0.05) of the household head. Respondents preferred raw (straight from the mound) and fried alate termites (AT) as compared to blanched and sundried termites which are mostly considered for preservation purposes (Van Huis et al. 2013). Additionally, consumption of blanched alates was significantly associated to occupation (p-value=0.023) and marital status (p-value=0.018) of the household head. However, gender had no scientific significance on choice of various preparation forms.

This implies that preference for either blanched, fried, sundried, or raw termites was influenced by respondents' socio-economic characteristics. Even though, whether fried or dried, alate termites contain 32–38% protein as per Taru & Chazovachii, (2015). Furthermore, the consumption rate of various forms was dependent on consumers' choices alluded by respondents as either being easy to prepare, tasty or nutritious.

4.3.1.2 Awareness of Purposes of Alate Termite Utilization

The potential uses of alate termites include health purposes, chicken feeding, diet supplement, due to poverty, or as staple (Figure 3). Slightly over half (53%) of the respondents utilized alate termites for chicken feeding, out of which 70% were female. This is in tandem with the report by Boafo et al. (2019), that only 11% of the respondents did not provide termites to their poultry in Ghana. This was expected since termites are collected from the wild and scavenging chicken would easily feed on them.

On the other hand, women are the common home keepers therefore would take care of their chicken. One of the women noted that they collect the termites and feed to the chicks that are not able to search for the termites. Additionally, women collected two other termite species subterranean and Kalotermitidae Vihiga county for chicken feeding as reported in Ghana (Boafo et al. 2019). Even though, gender did not significantly influence respondents' opinion on utilization of alate termites as chicken feed p-value> 0.05 (Table 6).

Household heads who had attained formal education (51%) used termites as feed. Out of which 38% were respondents with primary and secondary education, who purported to collect alates for feeding their chicken. However, those with tertiary education alluded that there are more health benefits associated with consumption of alate termites other than feeding them to poultry thus would be preferable source of household protein supplement. This could be because education promotes individuals' knowledge on potential benefits of edible insects.

More importantly, statistical association was realized between the use of late termites as chicken feed and respondents' level of education at p-value=0.026. This is probably because farmers with higher education have industrial or semi-industrial poultry farms which are less suitable for use of alate termites as the main source of protein. These farmers tend to stock a larger number of birds under intensive or semi-intensive systems and would require larger amounts of termites to feed their birds. According to Dao et al. (2020), termites are commonly used by smallholder farmers in West Africa to feed their poultry. Therefore, information on rearing systems and strategic future plays a key role in decision making by stockholders to ensure sustainable production. Likewise,

occupation of the household head significantly influenced utilization of alate termites for feed (p-value=0.019) especially during peak seasons. This is expected because occupation influences the scale of production thus small-scale farmers are more likely to feed alates to their chicken.

Over half of the respondents (65%) utilized the alate termites for health purposes, this is linked to the awareness on the nutritional potential (proteins, fats, and micronutrients) thus important in curbing malnutrition. One of the respondents a nutrition expert mentioned that alate termites are high in protein thus an important part of household diet. This is in tandem with nutritional reports in Kenya and other parts of the world (Ayieko et al. 2012; Kinyuru, 2013; Ijeomah et al. 2015). Therefore, termites can provide nutrients and food security for many households since it contains useful minerals which often lack in the diets. The nutritional potential of alate termites is comparable to crayfish which is presumed to have high protein content thus considered healthy for children growth (Ijeomah et al. 2015).

Moreover, respondents' occupation was significantly associated to use of alate termites for health purposes (p-value=0.037) (Table 7). Farmers (32%) acknowledged to utilize alate termites for health purposes. Since they attended several trainings by International Network of Food Data System (INFOODS) project thus aware on the nutritional potential of alate termites. Likewise, marital status influenced (X^2 =26.59, p-value=0.0322) the decision by household head to utilize alates for health purposes. This could be because those who are married (41%), are more cautious of the health status of the family. Even though, education status of household head had no statistical significance (p>0.05) on purposes of alate termite utilization.

Interestingly, only 6.8% of the respondents use alate termites due to low-income status (poverty). Level of education attainment (X^2=27.314, p-value=0.026) and occupation ($X^{2=}$35.94, p-value=0.0017) of household head were statistically significant (Table7). This could mean occupation and education attainment influences individuals' income level thus most households with higher education would not consider use of alates due poverty. Out of 6.8% majority had attained primary level of education with low economic status thus are greatly involved in termite collection and consumption since

it offers cheap protein. However, gender and marital status of had no significance ($p>0.05$) on collection of alates due to poverty.

4.3.1.3 Harvesting of Alate Termites

In this study 30% of the respondents participated in alate termite collection even though, harvesting was mostly done by women. This is consistent with the findings of Taru & Chazovachii (2015), who reported that females sometimes assisted by their children continue to dominate the termite trapping process. However, this study was conducted when children were in school and so this might have contributed to parity in the findings. Even though, men were not directly taking part in harvesting as mentioned by one of the respondents. They would clear bushes and trace termite mounds to facilitate easy harvesting by women, while others would collect alate termites late in the evening.

From the findings higher quantities of alate termites are reportedly harvested soon after the first rainfall during the long rainy season (42%), between March to June and short rains season around November to December (45%) with least quantities during drought periods as per Fombong & Kinyuru (2018). This slightly differs with the report by Boafo et al. (2019), that *Macrotermes* are higher quantities of termites are harvested throughout the year in Ghana. This could be attributed to varying ecological conditions of the area and the sub species harvested. Since alates are mainly harvested when they swarm to form new colonies.

Harvesters (57%) indicated that harvesting of alate termites is preferably in the afternoon and morning hours or late in the evening following showers of rain. Majorly, harvesting is done twice or three times in a week this was dependent on individual reasons as to harvest large quantities and avoid exploitation. Even though, during the rainy seasons the alates would swam daily thus collected for sale. This is comparable to harvesting of soldiers reported in Limpopo south Africa where harvesting is more often 3 days a week (29.73%), followed by 2 days (21.62%) and least 1day (5%) (Netshifhefhe et al. 2018).

Harvesters indicated that knowledge of the species to be harvested is based on indigenous knowledge which involves looking at the size of the termite and the type of wings, this somewhat contradicts the results by Netshifhefhe et al. (2018) that the harvesters used size, taste, and colour of termites as well as the mound type and size to identify the species in Limpopo South Africa. The missing links between the findings would be mainly because the study assessed harvesting of both the alates and the soldier termites.

Common harvesting methods within the study involved the use of the source of light to attract the alate termites which are then collected into containers as per Chavunduka (1975). However, new emerging techniques include use of a bucket placed upside down over an emergence hole/mound. This technique was used by (60%) of the respondents. This coincides with techniques reported in Limpopo SA where the termite hole is covered with sticks and leaves of either banana (*Musa paradisiaca Linnaeus* and *M. sapientum Linnaeus*) or *Peltophorum africanum (*Netshifhefhe et al. 2018). While in Ghana Fresh branches with leaves from any plant are used (Boafo et al. 2019).

In Vihiga the banana leaves are used with grass or plant debris which provide good shade for the alates as they fly to the bottom of the hole where they are trapped and harvested. Moreover, season simulation is also applicable to create microenvironment which stimulates the alates to emerge and swarm from wet grounds away from the mounds. The process involves locating the termite holes, wetting the soil and use of smoke. The process is coupled with music and drumming. Other locals beat the ground around termites' hill simulating heavy rain to provoke the termites to emerge. Conclusively, most popular, and easy way of harvesting is done during the evening hours, by placing a basin of water right under the light source. Surplus alates are preserved through sun drying (50%), pan-frying (41.66%) and refrigeration (8.33%). Even though, larger quantities are consumed raw (direct from the mound).

4.3.1.4 Factors Influencing Abundance of Alate Termites

The abundance of alate termites influences the extent of utilization. The respondents who had stayed in the area for more than 20 years (49.7%) alluded that there is variation in termite abundance over years. This is because they would tell varying quantities harvested over time. Ownership of termite mounds was reportedly low in the area as 65% harvesters do not own the mounds on individual land therefore, distance covered by harvesters was averagely less than 1 km while others walk 6-10km (62%) to the harvesting site.

This could have contributed to low quantities of harvest since the alates could emerge and be attracted by other sources of illumination as they swarm away from the mounds. Most points have been cleared to give room for crop production and settlement interfering with the termite hills. In Imo states Nigeria, higher quantities of alates are harvested directly from the mounds with low quantities harvested in areas away from mounds (Ijeomah et al. 2015).

Season and weather, type of soil in the locality and the continuous use of agrochemicals in harvesting sites were mentioned to contribute to variation in abundance. This coincides with results by Ijeomah et al. (2015) in selected communities in Nigeria that season is a major factor which determines its abundance of termite. This is because the alates take a ‘nuptial flight' during the rainy season making it more difficult to harvest from the base of the mounds. They are also noted that alates are mostly harvested late in the evening posing security concerns.

Level of education attainment of the household head was significantly associated with the influence of soil type (p-value=0.004), season (p-value=0.0.034) and continuous use of agrochemicals (p-value=0.009) on termite abundance (table 8). This implies that, formal education contributed to the knowledge of on the reduction in quantities of alate species per harvest in a specific area. On the other hand, respondents’ who had no formal education, indicated that they use traditional knowledge and skills but were able to note the change in quantities with limited knowledge on the contributing factors.

Additionally, awareness of termite availability regarding season was significantly associated with gender *(*p-value=0.002). This is because, females (61%) are more involved in harvesting than male thus, could easily tell the change in quantities per harvest. More importantly, awareness of termite availability by occupation was significantly associated with the soil type (p-value=0.025) and the use of agrochemicals (p-value=0.047). Most farmers (31%) alluded that availability and emergence of alate termites has been influenced by the type of soil, over exploitation and continuous use of agrochemicals that contributes to change in soil properties and mound characteristics. With the growing population and mass collection of alates would contribute to variation in termite abundance as well as changes in agroecological like amount of rainfall and microclimate of a specific area. The destruction of the mounds to give room for crop production was an issue of concern to the farmers.

4.3.2 Marketing of Alate Termites and Household Livelihood diversification

Objective two sought to assess collection and marketing of alate termites and its contribution to household livelihood. Further used gross margin analysis to quantify the amount of income (profitability) obtained through marketing.

4.3.2.1 Collection and Marketing of Alate Termites

Half of the harvesters take part in alate termite marketing, of which majority (34%) had been in the alate termite business for about 3-5 years, some 6-10 (28.1%) years. The business is predominantly done by women (71.8%), mostly men have not joined the business because termites vending was considered feminine and produced little profit. Out of which over 60.3% were married, women are more in the food business compared to men this existing condition might have impacted the findings.

Additionally, a higher percentage involved in marketing (62.5%) derived their livelihood from farming, compared to educationists and casual laborers. The survey results revealed that education level (p-value=0.014) and occupation (p-value=0.026) of the household head had significant influence on respondents' choice to participate in marketing. Income status of household plays key role in deciding to participate in a business and so alate termites. Even though, there was no statistical association of

gender with collection of alates for sale. This corroborates with findings of Adeoye et al. (2014).

Alate termites are marketed due to high quantities of supply during rainy seasons and availability of market. Mostly alates are sold in open markets in rented kiosks or open air within village and peri-urban centres, this is supported by reports in Kimilili sub-county by Kisaka (2018). Marketers sometimes hawk the termites to travellers, and this was perceived as a quick sale trick. Sensory characteristics that influenced buyers' choice includes smell and taste, as a measure of freshness. Contribution of alate termites to household livelihood depends on; quantities harvested and sold, relative price, amount of income obtained. Alate termite supply begins with the harvesters who sell to various marketers and consumers. Transportation was mainly by use of public service vehicles and motorbikes (as summarized in Figure 5).

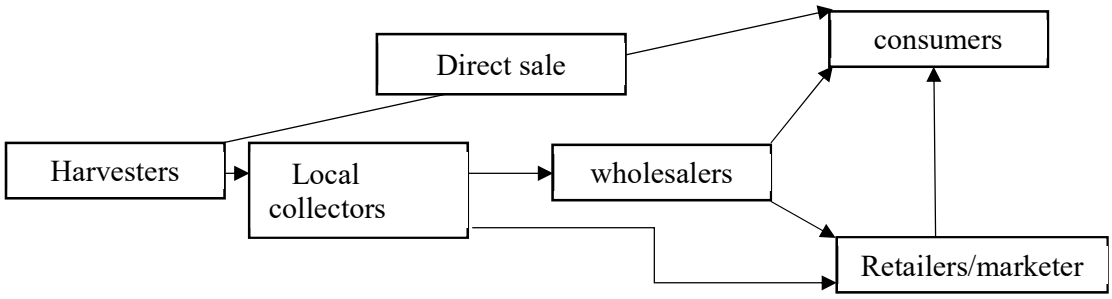

Figure 5: Supply chain of alate termites in Vihiga County
(Source: Author)

4.3.2.2 Profitability of Alate Termite Enterprise

The Gross profit for alate termite enterprise was calculated as a model for other marketers using various modes of transportation and the rural marketers. The return was still greater than zero, indicating profitability as per Abdullahi et al. (2017. Gross profit and gross profit margin both provide good indications of profitability of an enterprise based on their sales and costs of goods sold. However, the ratios might not be thorough measure of profitability since they don't include other operating expenses.

Alate termites are sold in open markets and rented kiosks, with the consumer bearing the cost of packaging as noted by most sellers. This study, however, did not place much emphasis on the Gross Profit obtained by actors involved in value addition but focused on returns by the local marketers. The retail price per kilogram was KES 500 that is comparable to the retailing price of goat meat. 24% of marketers obtained KES 600 profit per day while others obtained KES 300 profit per day. The average gross profit margin was 74.1% this translates that the business was profitable. However, amount of return for every marketer was dependent on the season and days of the week as higher profits were realized especially on market days. Therefore, alates are an important source of income for rural and urban dwellers (Adeoye et al. 2014). Therefore, marketers would realize good profit margins if they diversified products through value addition.

4.3.2.3 Alate Termites as A Source of Livelihood Diversification

Most households derived their livelihood from crop production (50.5%), livestock production (6%), wages (18%) and alate termite business (9%). Trading of alates is a remarkable source of livelihood, contributing to diet and income diversification, particularly during peak seasons. This is in tandem with reports from Kimilili sub-county, where commercialization of the (edible winged) termites is an alternative source of livelihood in rural and urban households (Kisaka, 2018).

Test of association between household sources of livelihood and alate termite marketing indicated a strong significance p-value=0.0058. This could be because several households involved in alate termite business earned money which could be put into diverse uses such as diet, clothing, and other household needs. This was similarly reported by Taru & Chazovachii (2015), the report further shows that alate termites are traded for income generation at local markets, as barter trade with traditional beer, and other crop produce. In absolute terms and when proportional to household income, annual income from alate was potential source of household livelihoods. Respondents confirmed that collection and marketing of alate termites was extremely useful in cushioning most households during periods immediately before the rainy seasons.

Further, multivariable regression model was used to quantify the benefits derived from alate termite marketing. Utilization purposes of alate termite was positively significant (p-value=0.003, $\beta = 0.755$) in determining the contribution of alate termites to household income and livelihoods (Table 10). Meaning a unit increase in utilization purpose would result in increased supply benefits derived from alate termites by 0.755. This implies that the decision by an individual on the diverse uses of the alates including chicken feeding, food supplementation, income generation, health benefits influence the benefits realized as shown in Figure 3. Furthermore, comparing with those involved in alate termite marketing, households that collected alate termites for consumption did not earn income but attained diet diversification.

Marketing of alate termites increases household purchasing power, allowing rural households to secure other needs such as clothing, school fees, and other necessities to sustain their livelihoods. On average half of the consumers sun-dried the alates and grounded into powder/flour which is used in backing/making other products such as buns (85), porridge flour (45), muffins (24) and crackers. The alate termite powder can be baked with other ingredients or processed and sold in both local and regional markets as reported by Van Huis et al. (2013); Ayieko et al. (2010). This would encourage rural industrialization to employ residents and complete the harvesting and commercialization chain.

4.3.2.4 Constraints to Commercialization of Alate Termites

There is scanty information about alate termite value addition, retailers sell fresh alate termites thus facing challenges of perishability. However, others used simple preservation methods to overcome this. Additionally, sources of alates were mentioned to be from the market (25.8%) even though marketers sourced alates from harvesters in other parts of the county due to increased demand. The increased demand led to rise in retail prices hence higher returns for households. However, this poses threat on the supply side, nevertheless, the entire edible-insect value chain has revealed its potential and still requires governance in terms of research, business incubation, and above all, legislation, and regulations (Niassy et al. 2018). Furthermore, policy makers in trying

to use edible insects to address food insecurity, should note insufficiency especially for seasonal edible insects alate termites included.

Even though, more than 500 species of edible insects are consumed in Africa (Kelemu et al. 2015), it is still a paradox especially in promoting year-round supply for the seasonal edible insects. For the continent, the development of suitable and sustainable technologies to increase quantities of insects for use on an industrial scale is a major challenge. The best strategies that could be envisaged to sustainably create a viable industry in alate utilization as food includes conserving and maximizing harvest from the wild in a sustainable manner, as well as the development of appropriate post-harvest handling practices.

4.3.2.5 Capacity Building Intervention for Marketers

Promoting alate termite commercialization and make it a viable enterprise would involve helping marketers to access credit facilities to expand the termite business. Notably as education attainment increases awareness of availability of credit facilities and regulations increased, implying that marketers would be helped to access credit as a capacity-building intervention to expand their businesses. Credit sources are mostly classified as either: formal, semi-formal or informal credit (Tasie, 2013). Formal is obtained from commercial banks or some credit funds while Informal from relatives, individual lenders, and associations however, semi-formal sector includes microfinance institution or NGOs, government-supported lending programs that aimed at promotion of exportation as well as processing of alates into finished products which would attract more consumers both regional and local to break the limitations of disgust factor.

Frequent training and creation of awareness by extension staff on sustainable harvesting is influenced by level of education attainment, indicating awareness on the need for trainings. This would enhance maintenance of the micro ecosystem for continuity in the termite colony. Sustainable harvesting would regulate mound destructions to promote habitat properties which contributes to termite abundance. Providing market links to marketers would also promote commercialization, especially of the processed products

which would attract higher prices in areas away from the harvesting sites either locally or globally. Additionally, value addition can be promoted to preserve the alate termites to extend shelf life beyond the harvesting season; this will expand the demand to new and international consumers through increasing the appeal and awareness of the nutritional and economic potentialities.

4.3.3 Contributions of alate Termites to Household Food Security

Objective three sought to determine the contribution of alate termite collection, marketing, and utilization to household food security in Vihiga county. Households are food secure when they can access sufficient, safe, and nutritious food that always meets their dietary needs and food preferences for an active and healthy lifestyle. The level of alate termite contribution to food security regarding the indicators are as summarized Table 11. Contribution of alate termites to food security was reportedly dependent on their availability, access, sustainability, adequacy, and nutritional potential. In terms of Nutrition the contribution was notably high (64.7%), followed by affordability. Compared to availability and access which were relatively low (table 10). Even though, termites are not controlled or owned by an individual, their utilization is not affected by Hardin's classical tragedy of the common phenomena thus are an infinite resource (Tarua & Chazovachii, 2015).

4.3.3.1 Availability of alate termites

Results revealed that education attainment was significantly associated with availability, access, affordability, sustainability, adequacy, and nutrition (Table 12). Occupation was significantly associated with affordability. Variation in availability of the alate termites influences the quantity collected (harvested), marketed and utilized which in turn influences the affordability (price per unit quantity) and access. For instance, during off season months (drought period), there is always general shortage of alate termites that force prices upward. The fluctuation in prices reflects in the variation on supply and demand.

On the other hand, during rainy season availability of alate termites in the market tend to rise due to increased emergence. The alates floods the market, however the prices

tend to remain constant since bulk buyers presume this to be the perfect time to buy the alates for preservation as well as for selling in different markets and neighbouring counties. This leads to substantial profit for the actors in the alate termite value chain, that has a positive influence on the household food security status. Most respondents acknowledge the use of income to secure other household requirements as well as secure balanced diet. Likewise, during peak supply period, the consumption rate tends to rise, as many collect from the mounds to use directly as part of the diet.

Previously, alate termites were widely available in western Kenya, and locals sold them in local markets. However, with the change in agricultural production and widespread use of synthetic fertilizers and pesticides in agriculture, the species is slowly dwindling, and respondents reported that they are losing their traditional food. This has been reported by Gahukar (2018), who detailed the disappearance of common insects in India, including bugs that were once part of the traditional diet. Termites (isoptera) are commonly regarded as crop pests, are destroyed by insecticide sprayings on crops including sugarcane, cotton, tobacco, and tea which they attack causing economic damages. As a result, rather than spraying, these insects can be collected and consumed. Large-scale collection can thus reduce the threat in crop fields while also saving money on chemicals.

4.3.3.2 Affordability of The Alate Termites

Affordability increased with increase in education level, as well as with possession of a stable employment. This showed great influence on the purchasing power of the consumer. Averagely as the monthly income of the respondent increased the expected quantity of alate termites consumed by a household increased. This means as income increases individuals' disposable income goes up hence increased purchasing power of consumers. This is complemented by (Kajale & Becker, 2015) who reported that, increase in income increased the consumers purchasing power of genetically modified food thus attaining food security and household livelihood. However, a higher monthly income will lower the expected quantity of alate termites consumed by urban dwellers, this could be because as income increases, the urban dwellers are able to access other animal protein sources thus reducing consumption of alate termites.

Agreement on the efficiency of alate termites to contribute to household nutrition seemed to be influenced by increase in level of education as well as possession of stable jobs. Which had appositive and significant effect on the quantity demanded of alates thus food security. This could be associated to the number of years an individual spent undergoing formal education increasing expected quantity of alate termites consumed in rural and urban households. More educated respondents could have acquired supplementary knowledge about the nutritional, and other benefits of alate termite consumption that developed positive perceptions on consumption of alates.

Kisaka (2018), when analysing the demand for Edible Winged Termites in Kimilili sub-county, Kenya reported that, higher education raised the consumers' living standards and increased their consciousness of nutritional aspect of food intake. Similarly, more educated consumers consumed more cheese than the less educated due to their awareness of its nutritional content importance (Rossini et al. 2015). The consumption rate of every food product is dictated by the consciousness of individuals who tend to mind what they eat. Therefore, education is key in changing individuals' behaviour, attitude and understanding that in turn could change their feeding habits. However, education level of respondents did not seem to influence awareness of utilization of alate termites in relation to sustainability. The aspect to ensure continuous supply of alates was disputed as 73.6% (Table 11) of the respondents pointed the low rate of alate termite sustainability.

Multivariable regression model was then used to establish how collection, marketing, and utilization of alate termites contribute to household food security. The model used the computed variables on alate termite utilization purpose, consumption patterns, termite abundance variance, quantity sold, and income obtained on the indicators of food security including Availability, sustainability, affordability, access, nutrition and adequacy. Variation in abundance of the alate termites had a significant positive effect on food security index (p-value<0.05; $\beta = 0.190$) as shown in Table 13. This affirms the findings in objective two of this study "Variation in abundance of alate termites' influences quantity harvested thus income and market returns" (Adeoye et al. 2014)

Abundance of alate termites determines the quantity harvested for marketing or household consumption. Several factors including type of soil, climatology and continuous use of excessive agrochemicals influences termite abundance (Figure 4). In times of higher supply, the consumption rate rises thus household supply of food increases beyond the normal index as a staple and side dish. However, at a 10% level of significance, utilization purposes would have a major impact on food security. On the other hand, quantity sold and income per season and consumption reason do not have a significant effect on food security.

The constant (B_0) being significant (p-value = 0.0) implies there could be other factors that influence food security other than the variables in consideration. Several other factors play role in ensuring household food security through utilization of alate termites, including degree of acceptance and willingness to pay and consume the alate termites as well as household participation in off-farm income generating activities. This could have a significant effect on purchase and consumption of other dietary prescriptions. Additionally, consumers and households that are involved in off-farm income generating activities are able to achieve food security through direct purchase of dietary needs as well as improved access to nutritional information and increased supplementary income increasing household disposable income that made consumers food secure as per Kisaka (2018).

A study conducted in Zimbabwe, reported a positive relationship between household food security and access to remittances (an alternative source of income) (Nyikahadzoi et al. 2012). Households with remittance access can buy more appropriate and nutritious foods than low-income groups. As a result, they are more likely to be food secure than those without this source of income. We thus anticipate a positive relationship between access to remittances and food security.

However, evidence from multi-collinearity analysis suggests that household-level dietary diversity is also strongly associated with per-capita consumption and energy availability, therefore, it could be a useful indicator of household food security situation. Research to quantify this association shows that a 1% increase in dietary diversity is associated with a 1% increase in per-capita consumption (Mango et al.

2014). Even though, the score cannot be used to estimate how much food is lacking because it cannot directly to quantify the amount of food consumed. Other factors determining whether a household is food secure include household size, access to market information, livestock wealth among others. However, this study revealed that achieving household food security through utilization of alate termites is significantly impacted by abundance variance at 5%.

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the conclusion of the study, recommendations, and suggested areas for further research

5.2 Conclusion

Based on the findings, alate termites are a significant source of protein that could be explored to promote household nutrition. This outlines the importance of alate termites in enhancing household diet diversification thus reducing cases of malnutrition and food insecurity. The consumption rate of alate termites is reportedly higher among various age groups due to associated health benefits. It is beneficial to children and women who require a high calorie diet and nutritious food. Additionally relative protein content can be harnessed to improve the nutrition of lactating women. The study shows the socio-economic status of the household heads to influence the consumption choices. Most preferred preparation form of alate termites was raw followed by fried in own oil. However, blanched and sun dried were mainly used as preservation techniques. Even though consumption was influenced by the individual preference for different preparation forms and awareness of potential benefits, insect palatability, taste, nutritional value also played a role in making consumption decisions. Despite termites serving as a cheap supplement for protein in the diets of many rural dwellers, species utilization is declining among younger generations and urban dwellers. Consumption of alate termites should therefore be promoted among city dwellers to realize its full potential.

Alate termites were also collected for other purposes including as chicken feed in some parts depending on the scale of poultry production as well as rearing systems, poverty or for income. Mostly harvested by use of light and other illumination to attract the alate termites. Harvesting of alates is dominated by women who are sometimes assisted by their children even though to some extent men also participated in harvesting. Harvesting is done mainly at the onset of long rains between March to June Mainly done three times a week to avoid over exploitation. Seasonality, excessive use of agrochemicals and type of soil influences the abundance of termites. Under some cases,

farmers must walk long distances to obtain them as just a few owned the termite mounds. Trapping techniques should therefore be promoted, and existing methods should be improved in areas where trapping is uncommon. Research should also be conducted on effective preservation methods to promote available during the off-season as well as improve processing technologies for the farmers to ensure continuous supply in the diets.

Based on the results, it may be concluded that the enterprise is profitable. Alate termites' business accounts for 9% of household's livelihood thus increasing household purchasing power. Commercialization is on the rise, households diversify sources of income to meet other household needs such as quality education, health care, and maternity care. Most households have embraced alate termite as a significant source of income and, in some cases, as a vehicle for economic empowerment of local communities through income diversification. However, short shelf life is one if the challenges facing the marketers. Other factors limiting commercialization include seasonality, risks of microbial load and perishability. These limits full potential that needs to be improved through research. The approach of entomophagy can be a useful tool in combating the global food crisis. However, there are other economic impacts of termite species especially “termites as pests” causing damage in crop fields this would influence choices on embracing this potential commodity.

5.3 Recommendation

1. Frequent training on value addition and other processing techniques would ensure increased shelf life and increased marketing options hence year-round supply of alate termite enriched food products. Several researchers have been making greater strides to promote production technologies of various edible insects. However, alate termites are seasonal mainly harvested from the wild therefore, to promote year-round supply, storage techniques through value addition could be viable options.

2. Acceptance of alate termites could be promoted through introduction in mainstream feeding programs in schools to ensure the acceptance over generations as household food security and nutrition booster.

3. There is need to promote awareness on the potential of the alate termites as an income diversification enterprise. Through continuous training masses should be educated on conservation to reduce specie extinctions this would help reduce exploitation and natural habitat destruction

4. Strengthen the food safety policy to ensure hygienic measures and sanitary standards are met to prevent cases of contamination throughout the handling steps.

5.4 Recommendations for Further Studies

i. Alate termites although is proven potential source of food and income, their seasonality would hinder their full potential thus, further research could investigate means on off season mass harvesting for continuous income flow. As well as include legal frameworks regulating the termite business.

ii. The study focused on alate termites that are not produced commercially. Therefore, further research can be conducted using other mass reared insects like crickets, to attest their economic potential.

REFERENCES

Abdullahi, S., Abdulwahab, K., & Abubakar, G. S. (2017). Gross margin analysis of modern groundnut oil extraction in Gombe metropolis Gombe State, Nigeria. *World Journal of Agricultural Research*, *5*(2), 58-63.

Adepoju, O. T., & Ajayi, K. (2021). Consumption pattern and acceptability of winged termites (Macroterme bellicosus)-enriched infant complementary foods in Ekiti State, Nigeria. *International Journal of Tropical Insect Science*, *41*(3), 2039-2050.

Adeoye, O. T., Alebiosu, B. I., Akinyemi, O. D., & Adeniran, O. A. (2014). Socio economic analysis of forest edible insects species consumed and its role in the livelihood of people in Lagos State. *Food Stud*, *3*, 104

Aiking, H. (2011). Future protein supply. *Trends in Food Science & Technology*, *22*(2-3), 112-120.

Alobo Loison, S. (2015). Rural livelihood diversification in sub-Saharan Africa: a literature review. *The Journal of Development Studies*, *51*(9), 1125-1138.

Amadi, E. N., & Kiin-Kabari, D. B. (2016). Nutritional composition and microbiology of some edible insects commonly eaten in Africa, hurdles and future prospects: A critical review. *Journal of Food: Microbiology, Safety & Hygiene*, *1*(1), 1000107.

Anankware, J. P., Osekre, E. A., Obeng-Ofori, D., & Khamala, C. (2016). Identification and classification of common edible insects in Ghana. *International Journal of Entomology Research*, *1*(5), 33-39.

Aschemann-Witzel, J., Ares, G., Thøgersen, J., & Monteleone, E. (2019). A sense of sustainability –How sensory consumer science can contribute to sustainable development of the food sector. *Trends in food science & technology*, *90*, 180-186.

Ayieko, M. A., Obonyo, G. O., Odhiambo, J. A., Ogweno, P. L., Achacha, J., & Anyango, J. (2011). Constructing and Using a Light Trap Harvester: Rural Technology for Mass Collection of Agoro Termites (" Macrotermes subhylanus"). *Research Journal of Applied Sciences, Engineering and Technology*, *3*(2), 105-109.

Ayieko, M., Oriaro, V., & Nyambuga, I. A. (2010). Processed products of termites and lake flies: improving entomophagy for food security within the Lake Victoria region. *African Journal of Food, Agriculture, Nutrition and Development*, *10*(2).

Ayieko, M. A., Kinyuru, J. N., Ndong'a, M. F., & Kenji, G. M. (2012). Nutritional value and consumption of black ants (Carebara vidua Smith) from the Lake Victoria region in Kenya. *Advance Journal of Food Science and Technology*, *4*(1), 39-45.

Ayieko, A. (2014). Review on community food security and edible insects resources: Biodiversity and policy implications for safeguarding human consumption.

Backwell, L., & d'Errico, F. (2005). The origin of bone tool technology and the identification of early hominid cultural traditions. *From tools to symbols: from early hominids to modern humans*, 238-275.

Backwell, L. R., & d'Errico, F. (2001). Evidence of termite foraging by Swartkrans early hominids. *Proceedings of the National Academy of Sciences*, *98*(4), 1358-1363.

Backwell, L., & d'Errico, F. (2008). Early hominid bone tools from Drimolen, South Africa. *Journal of Archaeological Science*, *35*(11), 2880-2894.

Bandura, A., & Walters, R. H. (1977). *Social learning theory* (Vol. 1). Prentice Hall: Englewood cliffs.

Bandura, A. (1985). Model of causality in social learning theory. In *Cognition and psychotherapy* (pp. 81-99). Springer, Boston, MA.

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

Boafo, H. 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. *Insects*, *10*(3), 69.

Bodenheimer, F. S. (2013). *Insects as human food: a chapter of the ecology of man*. Springer.

Bongaarts, J. (2009). Human population growth and the demographic transition. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1532), 2985-2990.

Chavunduka, D. M. (1975). Insects as a source of protein to the African. *Rhodesia Sci. News*, *9*, 217-220.

Dao, A. N. C., Sankara, F., Pousga, S., Coulibaly, K., Nacoulma, J. P., Ouedraogo, S., ... & 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.

DeFoliart, G. (1990). Insects as food in indigenous populations. *Ethnobiology: implications and applications*, 145-150.

Desilva, J., & Lesnik, J. (2006). *Chimpanzee Neonatal Brain Size : Implications for Brain Growth in Homo Erectus*. *51*. https://doi.org /10.1016/j.jhevo l.200 6.05.0 06

Djurfeldt, A. A., & Djurfeldt, G. (2013). *Structural Transformation and African Smallholders : Drivers of Mobility within and between the Farm and Non-farm Sectors for Eight Countries Structural Transformation and African Smallholders : Drivers of Mobility within and between the Farm and Non-farm Sectors for Eight Countries*. *0818*. https://doi.org/10.1080/136008 18.2013.8 17 550

Dzerefos, C. M., & Witkowski, E. T. (2015). Crunchtime: sub-Saharan stinkbugs, a dry season delicacy and cash cow for impoverished rural communities. *Food Security*, *7*(4), 919-925.

Ekpo, K. E., Onigbinde, A. O., & Asia, I. O. (2009). Pharmaceutical potentials of the oils of some popular insects consumed in southern Nigeria. *African Journal of Pharmacy and Pharmacology*, *3*(2), 051-057.

Ellis, F. (2000). *The Determinants of Rural Livelihood Diversification i n Developing Countries*. *51*(2), 289–302.

Emmanuel, E. A. (2011). Rural livelihood diversification and agricultural household welfare in Ghana. *Journal of Development and Agricultural Economics*, *3*(7), 325-334.

FAO. (2009). Principles and methods for the risk assessment of chemicals in food. *Environmental Health Criteria*, *240*.

FAO, 2002. The State of Food Insecurity in the World 2001. FAO, Rome

FAO. (2010). Forest insects as Food: Humans Bite Back. In *Rap* . https://doi.org/ ISBN 978-92-5-106488-7

FAO. (2013).The state of food security:The multiple dimension of food security.

FAO. (2017) Regional overview of food security and nutrition in Africa. The food security and nutrition–conflict nexus: building resilience for food security, nutrition, and peace. Accra; 2017.

FAO, 2018. *Food and agriculture data.* [online] Available at: <http://www.fao.org/faostat/en/#country

Fombong, F. T., & Kinyuru, J. N. (2018). Termites as food in Africa. *Termites and Sustainable Management*, 217-240.

Frank, B., & Enkawa, T. (2008). Does aggregate income influence satisfaction with the standard of living?. *International Journal of Society Systems Science*, *1*(2), 113-131.

Gahukar, R. T. (2018). Entomophagy for nutritional security in India: potential and promotion. *Current Science*, *115*(6), 1078-1084.

Gahukar, R. T. (2011). Entomophagy and human food security. *International Journal of Tropical Insect Science*, *31*(3), 129-144.

Ghazoul, J. (2006). Floral diversity and the facilitation of pollination. *Journal of ecology*, *94*(2), 295-304.

Ghosh, S., Debelo, D. G., Lee, W., Meyer-Rochow, V. B., Jung, C., & Dekebo, A. (2020). Termites in the human diet: an investigation into their nutritional profile. In *African Edible Insects as Alternative Source of Food, Oil, Protein and Bioactive Components* (pp. 293-306). Springer, Cham.

Government of Kenya (2017). *THE 2017 LONG RAINS SEASON ASSESSMENT REPORT. Nairobi.*

GOK. (2013). National Climate Change Action Plan 2013-2017. *Government Printer. Nairobi*.

Hazzi, O., & Maldaon, I. (2015). A pilot study: Vital methodological issues. *Business: Theory and Practice*, *16*(1), 53-62.

Iannuzzi, E., Sisto, R., & Nigro, C. (2019). The willingness to consume insect-based food: an empirical research on Italian consumers. *Agricultural Economics*, *65*(10), 454-462.

I. C. F. Macro. (2010). *Kenya demographic and health survey 2008-09*. KNBS.

Igwe, C. U., Ujowundu, C. O., Nwaogu, L. A., & Okwu, G. N. (2011). Chemical analysis of an edible African termite Macrotermes nigeriensis, a potential antidote to food security problem. *Biochemistry and Analytical Biochemistry*, *1*(105), 2161-1009.

Ijeomah, H. M., Oyebade, B. A., & Mazi, E. C. (2015). Utilization of edible winged termite (Macrotermes natalensis) in selected communities of Imo and Rivers States, Nigeria. *International Journal of Scientific & Engineering Research*, *6*(9), 919-940.

Intergovernmental Panel on Climate Change. (2006). *2006 IPCC guidelines for national greenhouse gas inventories*. Intergovernmental Panel on Climate Change.

Jongema, Y. (2017). List of edible insects of the world. *Wageningen: Laboratory of Entomology, Wageningen University*.

Jumbe, C. B., Bwalya, S. M., & Husselman, M. (2008). Contribution of dry forests to rural livelihoods and the national economy in Zambia. *Managing the miombo woodlands of southern Africa*.

Kajale, D. B., & Becker, T. C. (2015). Willingness to pay for golden rice in India: a contingent valuation method analysis. *Journal of Food Products Marketing*, *21*(4), 319-336.

Kelemu, S., Niassy, S., Torto, B., Fiaboe, K., Affognon, H., Tonnang, H., ... & 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.

Kenya National Bureau of Statistics; Ministry of Health/Kenya; National AIDS Control Council/Kenya; Kenya Medical Research Institute; National Council for Population and Development/Kenya; ICF International. Kenya Demographic and Health Survey 2014; Rockville, MD, USA, 2015

Kim, S. W., Less, J. F., Wang, L., Yan, T., Kiron, V., Kaushik, S. J., & Lei, X. G. (2019). Meeting global feed protein demand: challenge, opportunity, and strategy. *Annu. Rev. Anim. Biosci*, *7*(1), 221-243.

Kinyuru, J. N., Kenji, G. M., Njoroge, S. M., & Ayieko, M. (2010). Effect of Processing Methods on the in Vitro Protein Digestibility and Vitamin Content of Edible Winged Termite (Macrotermes Subhylanus) and Grasshopper (Ruspolia Differens). *Food and Bioprocess Technology*, *3*(5), 778–782. https://doi.org/ 10.1007/s11947-009-0264-1

Kinyuru, J. N., Konyole, S. O., Roos, N., Onyango, C. A., Owino, V. O., Owuor, B. O., Estambale, B. B., Friis, H., Aagaard-Hansen, J., & Kenji, G. M. (2013). Nutrient Composition of Four Species of Winged Termites Consumed in Western Kenya. *Journal of Food Composition and Analysis*, *30*(2), 120–124. https://doi.org /10.1016/j.jfca.2013.02.008

Kinyuru, J., O. Konyole, S., M. Kenji, G., A. Onyango, C., O. Owino, V., O. Owuor, B., B. Estambale, B., Friis, H., & Roos, N. (2012). Identification of Traditional Foods with Public Health Potential for Complementary Feeding in Western Kenya. *Journal of Food Research*, *1*(2). https://doi.org/10.5539/jfr.v1n2p148

Kisaka, C. N. (2018). *Evaluation of consumers acceptance and pricing of edible winged termites (Macrotermes subhylanus) in Kimilili Sub-County, Kenya*

KNBS, G. (2019). Economic survey 2019. *Kenya national bureau of statistics*.

Korir, L., Rizov, M., & Ruto, E. (2020). Food security in Kenya: Insights from a household food demand model. *Economic Modelling*, *92*, 99-108.

Kothari, C. R. (2004). *Research methodology: Methods and techniques*. New Age International.

Lensvelt, E. J. S., & Steenbekkers, L. P. A. (2014). *Ecology of Food and Nutrition Exploring Consumer Acceptance of Entomophagy : A Survey and Experiment in Australia and the Netherlands Exploring Consumer Acceptance of Entomophagy : A Survey and Experiment in Australia and the Netherlands*. *November*, 37–41. https://doi.org/10.1080/03670244.2013.879865

Malaisse, F. (2005). Human consumption of Lepidoptera, termites, Orthoptera, and ants in Africa. *Ecological implications of minilivestock*, 175-230.

Mango, N., Zamasiya, B., Makate, C., Nyikahadzoi, K., & Siziba, S. (2014). Factors influencing household food security among smallholder farmers in the Mudzi district of Zimbabwe. *Development Southern Africa*, *31*(4), 625-640.

Manjur, K., Amare, H., HaileMariam, G., & Tekle, L. (2014). Livelihood diversification strategies among men and women rural households: Evidence from two watersheds of Northern Ethiopia. *Journal of Agricultural Economics and Development*, *3*(2), 17-25.

Mellos, K. (1988). Neo-Malthusian Theory. In *Perspectives on Ecology* (pp. 15-42). Palgrave Macmillan, London.

Mc Carthy, U., Uysal, I., Badia-Melis, R., Mercier, S., O'Donnell, C., & Ktenioudaki, A. (2018). Global food security–Issues, challenges and technological solutions. *Trends in Food Science & Technology*, *77*, 11-20.

MOH, K. (2015). Kenya stepwise survey for non communicable diseases risk factors 2015 report. *Division of Noncommunicable Diseases*.

Momanyi, D. K., Owino, W. O., Makokha, A., Evang, E., Tsige, H., & Krawinkel, M. (2019). Gaps in food security, food consumption and malnutrition in households residing along the baobab belt in Kenya. *Nutrition & Food Science*.

Morgan, P. (2006). The concept of capacity. *European Centre for Development Policy Management*, 1-19.

Mugenda, O. M., & Mugenda, A. G. (2003). Research Methods: Sample size determination. *African Centre For Technology Studies*.

Muimba-Kankolongo, A., Ng'andwe, P., Mwitwa, J., & Banda, M. K. (2015). Non-Wood Forest Products, Markets, and Trade. In *Forest Policy, Economics, and Markets in Zambia* (pp. 67-104). Academic Press.

Muro, M., & Jeffrey, P. (2008). *A Critical Review of the Theory and Application of Social Learning in Participatory Natural Resource Management Processes*. *0568*(May). https://doi.org/10.1080/09640560801977190

Muyanga, M., & Jayne, T. S. (2014). Effects of Rising Rural Population Density on Smallholder Agriculture in Kenya Effects of Rising Rural Population Density on Smallholder Agriculture in Kenya. *Journal of Food Policy*, *July*. https://doi.org/10.1016/j.foodpol.2014.03.001

Netshifhefhe, S. R., Kunjeku, E. C., & Duncan, F. D. (2018). Human uses and indigenous knowledge of edible termites in Vhembe District, Limpopo Province, South Africa. *South African Journal of Science*, *114*(1-2), 1-10.

Niaba Koffi, P. V., Kouakou, B., Gildas, G. K., Thierry, A., N'golo, K., & Dago, G. (2013). Quality characteristics of biscuits made from sorghum and defatted Macrotermes subhyalinus. *International Journal of Biosciences (IJB)*, *3*(1), 58.

Niassy, S., Musundire, R., Ekesi, S., & Huis, A. V. (2018). *Edible Insect Value chains in Africa*. *December*. https://doi.org/10.3920/JIFF2018.x005

Nyeko P, Olubayo FM. (2005) Participatory assessment of farmers 'experiences of termite problems in agroforestry in Tororo District, Uganda. Agricultural Research and Extension Network Paper.; January, Art. #143, 20 pages.: https://www.odi.org/sites/odi.org.uk/files/odi-assets/ -opinion-files/5172.pdf

Nyikahadzoi, K., Siziba, S., Mango, N., Mapfumo, P., Adekunhle, A., & Fatunbi, O. (2012). Creating food self reliance among the smallholder farmers of eastern Zimbabwe: exploring the role of integrated agricultural research for development. *Food Security*, *4*(4), 647-656.

Odhiambo, C. O., Wasike, C. B., & Ogindo, H. O. (2019). Effect of socio-demographic characteristics on Kenyan smallholder dairy farmers' adaptive strategies to climate change effects. *Atmospheric and Climate Sciences*, *9*(4), 583-599.

Oduor, F. O., Boedecker, J., Kennedy, G., & Termote, C. (2019). Exploring agrobiodiversity for nutrition: Household on-farm agrobiodiversity is associated with improved quality of diet of young children in Vihiga, Kenya. *PLoS One*, *14*(8), e0219680.

Ogello, E. O., & Munguti, J. M. (2016). Aquaculture: a promising solution for food insecurity, poverty and malnutrition in Kenya. *African Journal of Food, Agriculture, Nutrition and Development*, *16*(4), 11331-11350.

Olsen, C., & St George, D. M. M. (2004). Cross-sectional study design and data analysis. *College entrance examination board*, *26*(03), 2006.

Olum, S., Wesana, J., Mawadri, J., Nakiranda, J. K., & Odongo, W. (2021). Insects as food: Illuminating the food neophobia and socio-cultural dynamics of insect consumption in Uganda. *International Journal of Tropical Insect Science*, *41*(3), 1-10.

Omotoso, O. T. (2006). Nutritional Quality, Functional Properties and Anti-Nutrient Compositions of the Larva of Cirina Forda (Westwood) (Lepidoptera: Saturniidae). *Journal of Zhejiang University. Science. B.*, *7*(1), 51–55. https://doi.org/10.1631/jzus.2006.B0051

Pal, P., & Roy, S. (2014). Edible insects: future of human food–a review. *International Letters of Natural Sciences*, *21*.

Payne, C. L. R. (2020). Moths & Legends The contribution of chitoumou, *the edible caterpillar Cirina butyrospermi, to food security, agriculture and biodiversity in a low-intensity agroforestry system*.

Payne, C. L. R. (2015). Wild harvesting declines as pesticides and imports rise: the collection and consumption of insects in contemporary rural Japan. *Journal of Insects as Food and Feed*, *1*(1), 57-65.

Popp, J., Oláh, J., Kiss, A., & Lakner, Z. (2019). Food security perspectives in sub-Saharan Africa. *Amfiteatru Econ*, *21*(51), 361-376.

Rosegrant, M. W., & Cline, S. A. (2003). Global food security: challenges and policies. *Science*, *302*(5652), 1917-1919.

Rossini, G., Vicentin, J., & Depetris, E. (2015). *Household cheese consumption in Argentina: A double-hurdle model estimation* (No. 713-2016-48581).

Ruby, M. B., Rozin, P., & Chan, C. D. (2015). Determinants of willingness to eat insects in the USA and India. *Journal of Insects as Food and Feed*, *1*(3), 215-225.

Ruel, M. T., Garrett, J., Yosef, S., & Olivier, M. (2017). Urbanization, food security and nutrition. *Nutrition and health in a developing world*, 705-735.

Salako, A. A., Olubanjo, O. O., & Okeowo, T. A. (2013). Comparative Cost-Returns Structures of Irrigated and Rainfed Arable Crops Production in Ogun-Oshun River Basin Development Authority Project Areas. *International Journal of Food and Agricultural Research*, *10*(1&2), 34-42.

Seni, A. (2017). Edible insects: Future prospects for dietary regimen. *Int. J. Curr. Microbiol. Appl. Sci*, *6*, 1302-1314.

Séré, A., Bougma, A., Ouilly, J. T., Traoré, M., Sangaré, H., Lykke, A. M., ... & Bassolé, I. H. N. (2018). Traditional knowledge regarding edible insects in Burkina Faso. *Journal of ethnobiology and ethnomedicine*, *14*(1), 1-11.

Slovin, E. (1960)"Slovin's Formula for Sampling Technique.[Paper reference 1]."

Start, D., & Start, D. (2001). The Rise and Fall of the Rural Non-farm Economy *: Poverty Impacts and Policy Options*. *19*(4), 491–505.

Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, eds. 2006. Livestock's Long Shadow: Environmental Issues and Options. Rome: Food Agric. Organ. 319 pp.

Taru, J., & Chazovachii, B. (2015). Rural households' livelihoods diversification through termite utilization in depressed region of Zimbabwe. *Chinese Journal of Population Resources and Environment*, *13*(4), 373-378.

Tasie, C. M. (2013). Effects of international fund for agricultural development (IFAD) credit supply on rural farmers in Rivers State, Nigeria. *Journal of Development and Agricultural Economics*, *5*(5), 186-191.

Timmer, C. P. (2009). *A world without agriculture: The structural transformation in historical perspective* (p. 96). Washington, DC: Aei Press.van Huis, Arnold. (2013). Potential of Insects as Food and Feed in Assuring Food Security. *Annual Review of Entomology*, *58*(1), 563–583. https://doi.org/ 10.1 146/annurev-ento-120811-153704

Turk, J. (2016). Meeting projected food demands by 2050: Understanding and enhancing the role of grazing ruminants. *Journal of Animal Science*, *94*(suppl_6), 53-62.

UNEP,F.(2012).Principles for sustainable insurance. https://www.unepfi.org/ wordpress/wp-content/uploads/

USAID.,2017a."CountryProfile:Kenya.":http://www.feedthefuture.gov/country/kenya

Van Huis, A. (2003). Insects as food in sub-Saharan Africa. *International Journal of Tropical Insect Science*, *23*(3), 163-185.

Van Huis, A. (2013). Van ltterbeeck J, Klunder H, Mertens E, Halloran A, Muir G, et al. *Edible insects: future prospects for food and feed security. Rome: Food and agriculture Organization of the United Nation*, 1-88.

Van Huis, Arnold. (2016). Edible Insects are the Future? *Proceedings of the Nutrition Society*, *75*(3), 294–305. https://doi.org/10.1017/S0029665116000069.

van Huis, Arnold. (2017). Cultural Significance of Termites in Sub-Saharan Africa. *Journal of Ethnobiology and Ethnomedicine*, *13*(1), 1–12. https://doi .org/ 1 0 . 1186/s13002-017-0137-z

World Bank. (2017). *The growing role of minerals and metals for a low carbon future*. World Bank.

World Bank, (2018). The World Bank data, Prevalence of undernourishment (% of the population.

APPENDICES

Appendix 1: Questionnaire

Survey on Utilization of alate termites.

Dear respondent.

My name is Samantha Akoth Anyuor, a student at Jaramogi Oginga Odinga University of Science and Technology undertaking research on **Utilization of Alate Termites.** This questionnaire is for collecting data concerning harvesting, marketing, and utilization of termites. The information obtained from you as a respondent will be treated with utmost confidentiality and will only be used for the purpose of this research. I therefore appeal to you to kindly fill the questionnaire with utmost honesty. Participation is voluntary and your response is valued for the success of the research. Thank you.

SECTION A: Respondent Demographic Information

1. Sex: male [ ] Female [ ].
2. Age: 1-14years [ ] 15-24 [ ] 25-44 [ ] 45-64 [ ] 65 Above [ ].
3. Marital status Married [ ] Single [ ] Divorced [ ] Widow/ Widower [ ]
4. Highest Education Level: Primary [ ] Secondary [ ] Tertiary [ ] None [ ]
5. Occupation: …….
6. Duration of stay in the area: ……
7. Are you involved in any other activities that are not on-farm? Yes [ ], No [ ] .
8. What is the size of your Household?.....

SECTION B: Farmers Capacity; Knowledge, Attitude and Practices On Collection and Utilization Of Termites

9. Do you consume alate termites?

   Yes [ ] No [ ]

   Kindly indicate the extent to which you agree with the statements below.

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

S/N	Statements	1	2	3	4	5
10	I eat alate termites because they have a good taste					

11	I eat alate termites because they are nutritious.					
12	I eat alate termites because they have pleasant smell					
13	Alate termites are easy to prepare					

In what form do you prefer termites. Kindly tick against each statement where;

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

S/N	Statements	1	2	3	4	5
14	I would eat alate termites that are fried.					
15	I would eat blanched termites					
16	I would eat sun-dried termites					
17	I would eat raw termites					

Kindly indicate (tick in the table) the extent to which you agree or disagree with the highlighted statements on Utilization of termites.

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

S/N	Indicators	1	2	3	4	5
18	I collect alate termites to feed my chicken					
19	I collect termites as a source of income					
20	Alate termites are very nutritious					
21	I eat termites as a staple food					
22	I supplement termites with other food from the farm					
23	I collect alate termites for health reasons					
24	I eat termites because of poverty					
25	Termites are food for famine periods only					

26. Do you harvest alate termites? Yes [ ] No [ ]
27. For how long have you been involved in harvesting?.....
28. Apart from the alate termites what other types of termites do you collect?
……
29. What is your preferred time of harvesting the alate termites?
……
30. How many times in a year, do you harvest the alate termites in your area?
……
31. Which season in a year do you harvest high quantity of alate termites?
……
32. How do you identify the species of edible termites for harvesting?
……
……
33. Do you own a termite mound Yes [ ] No [ ]
34. What distance do you cover averagely to the mounds for harvesting?
……
35. What method of collection do you use?
……
……
36. Would you list some of the new technologies used in harvesting of alates if any.……
37. How do you preserve the alate termites after collection?
……
……
38. Have you received training on termite collection and utilization?
Yes [ ] No [ ]
39. which organization/institution offers the trainings?
Governmental [ ] Non-governmental [ ] Governmental/Non-governmental [ ] None [ ]
40. How many times have you attended the trainings?.....……

The following statements are related to termite collection Kindly indicate (tick in the table) the extent to which you agree with the highlighted statements

1-Stongly Disagree **2**-Disagree **3**-Neutral 4- Agree **5**- Strongly Agree

S/N	Termite abundance and Collection	1	2	3	4	5
41	Termites abundance vary with type of soil					
42	Farmers receive trainings on sustainable harvesting of termites.					
43	Termites abundance vary with season					
44	use of agro-chemicals influence termite abundance over time					
45	There is difference in harvest quantity based on agro-ecological conditions in your community.					

SECTION C: TERMITE COLLECTION AND HOUSEHOLD INCOME

46. Do you collect termites for sale? Yes [ ] No [ ]
47. For how many years have you been in the termite business?

    ……

    ……
48. What quantity do you harvest from a single mound in kg?

    ……

    …….....
49. What is the sum quantity of alate termite harvested per season?

    ……
50. What is the quantity sold/transported per season?

    ……
51. What is the average distance that you cover to the nearest trading market?

    ……
52. What is the preferred means of transporting the termites to the market?

    ……
53. What is the average cost of transportation per KM……?

54. How much income do you get in a season from the sale of termites?

……..……

55. How do you preserve surplus termites at the end of the market day?

……

56. What are the features that influence choice of termites by consumers?

Taste [ ] Texture [ ] Smell [ ] Appearance [ ] other […]……

57. What is the price of 1kg termites in the market? ……..

58. Do you practice value addition/processing of alate termites Yes [ ] No [ ]

59. Does value addition improve pricing of termites? Yes [ ] No [ ]

60. List some of the processed products.

……

61. What is the main source of livelihood in your household?

……

62. What are the other sources of income to your household?

……

Kindly indicate (tick in the table) the extent to which you agree with the highlighted statements **1**-Strongly Disagree **2**-Disagree **3**-Neutral 4- Agree **5**- Strongly Agree

S/N	**Termite collection and Livelihood Diversification**	1	2	3	4	5
63	Commercialization has promoted your income level					
64	There is enough supply of termites from the market					
65	Termite utilization have led to improved diets					

Kindly tick against each statement on what should be done to promote utilization of termites as a source of household livelihood. Where **1**-Stongly Disagree **2**-Disagree. **3**-Neutral **4**- Agree **5**- Strongly Agree

S/N	**Statements**	1	2	3	4	5
66	Helping farmers to access to credit facilities					

67	Offering frequent trainings utilization of alate termites					
68	Mobilization/creation of awareness by extension agents					
69	Helping farmers to access markets to obtain more income					

SECTION D: FOOD SECURITY

How do you rate utilization of alate termites with regard to household food security? Kindly tick on the boxes below.

S/N	Indicators	Not at all	Very low	Low	High	Very high
70	Availability					
71	Access					
72	Affordability					
73	Stability/ sustainability					
74	Adequacy					
75	Nutrition					

Appendix 2: NACOSTI Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **315851**

Date of Issue: **24/September/2021**

RESEARCH LICENSE

This is to Certify that Miss.. SAMANTHA AKOTH ANYUOR of Jaramogi Oginga Odinga University of Science and Technology, has been licensed to conduct research in Vihiga on the topic: POTENTIAL OF ALATE TERMITES (Macrotermes Spp) AS AN ENTERPRISE TO IMPROVED FOOD SECURITY AMONG HOUSEHOLDS IN VIHIGA COUNTY-KENYA for the period ending : 24/September/2022.

License No: **NACOSTI/P/21/13050**

315851

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

Appendix 3: JOOUST ERC Approval

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/E2

28th September, 2020

Samantha Anyuor
SAFS
JOOUST

Dear Ms. Anyuor,

RE: APPROVAL TO CONDUCT RESEARCH TITLED "UTILIZATION OF ALATE TERMITES (MACROTERME SPP) FOR IMPROVED FOOD SECURITY AMONG HOUSEHOLDS IN VIHIGA COUNTY"

This is to inform you that JOOUST ERC has reviewed and approved your above research proposal. Your application approval number is **7/16/1/20-2**. The approval period is from 28th September, 2020 – 27th September, 2021.

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 4: JOOUST BPS Authorization Letter

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: A451/4256/2018

Date: 17th August 2020

TO WHOM IT MAY CONCERN

RE: ANYUOR SAMANTHA AKOTH - A451/4256/2018

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: ***"Potential of Alate Termites (Macrotermes Spp) as an Enterprise to Improved Food Security among Households in Vihiga County -Kenya".***

Any assistance accorded to him 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

Appendix 5: SPSS Variable Computation Script

```
DATASET ACTIVATE DataSet1.
COMPUTE consumption_reason=MEAN(hhxtics_utilizationgoodtaste,hhxtics_utilizationnutritious,
    hhxtics_utilizationpleasant_smell,hhxtics_utilizationeasy_preparation).
EXECUTE.

COMPUTE preferences=MEAN(hhxtics_utilizationfriedtermites_eating,
    hhxtics_utilizationblanchedtermites_eating,hhxtics_utilizationsundried_termites_eating,
    hhxtics_utilizationrawtermites_eating).
EXECUTE.

COMPUTE purpose=MEAN(hhxtics_utilizationchickenfeed,hhxtics_utilizationincomesource,
    hhxtics_utilizationstaplefood,hhxtics_utilizationfoodsupplement,hhxtics_utilizationhealthreasons,
    hhxtics_utilizationeatingforpovertyreasons,hhxtics_utilizationfoodforfamine).
EXECUTE.

COMPUTE abundance_variance=MEAN(hhxtics_utilizationabundance_vary_with_soil,
    hhxtics_utilizationtrainings_on_sustainable_harvesting,
    hhxtics_utilizationabundance_vary_with_season,hhxtics_utilizationagrochemicals_influence_abundance,
    hhxtics_utilizationagroecological_influece).
EXECUTE.

COMPUTE supply_benefits=MEAN(collection_hhincomecommerc_promoted_income,
    collection_hhincomeenough_marketsupply,collection_hhincomeimproved_diets).
EXECUTE.

COMPUTE utilization_promo=MEAN(collection_hhincomeaccess_to_credits,
    collection_hhincomefrequent_trainings,collection_hhincomeawareness_by_extension,
    collection_hhincomeacces_to_markets).
EXECUTE.

COMPUTE food_security=MEAN(collection_foodsecurityAvailability,collection_foodsecurityAccess,
    collection_foodsecurityAffordability,collection_foodsecurityStability_sustainability,
    collection_foodsecurityAdequacy,collection_foodsecurityNutrition).
EXECUTE.

recode food_security (0 thru 3.49 = 0) (3.5 thru highest = 1) into food_security_cat.
execute.

CTABLES /TABLE (commerc_promoted_income + enough_marketsupply + improved_diets)[COUNT ROWPCT]
  /CLABELS ROWLABELS=OPPOSITE
  /CATEGORIES VARIABLES=commerc_promoted_income enough_marketsupply improved_diets TOTAL=YES.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF COLLIN TOL
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT supply_benefits
  /METHOD=ENTER purpose_utilization quantity_sold_per_season income_per_season.

   CTABLES /TABLE (Availability + Access + Affordability + Sustainability + Adequacy + Nutrition)[COUNT ROWPCT]
  /CLABELS ROWLABELS=OPPOSITE
   /CATEGORIES VARIABLES=Availability Access Affordability Sustainability Adequacy Nutrition TOTAL=YES.

REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF COLLIN TOL
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT food_security
  /METHOD=ENTER purpose_utilization abundance_variance quantity_sold_per_season income_per_season
consumption_reason.
```

Appendix 6: Sample R-script for Pearson's Chi square tests

```
Call:
lm(formula = attitudesum ~ Sex + Age + Mstatus + education +
    Occupation, data = eliteTemite)

Residuals:
    Min      1Q  Median      3Q     Max
-6.4063 -2.9194 -0.5916  3.0640  7.0613

Coefficients:
                       Estimate Std. Error t value Pr(>|t|)
(Intercept)             12.4265     2.7977   4.442 1.74e-05 ***
SexMale                 -0.4145     0.6350  -0.653   0.5149
Age1-14years            -0.3126     2.3704  -0.132   0.8953
Age15-24                -2.9745     1.7255  -1.724   0.0868 .
Age25-44                -3.3762     1.4993  -2.252   0.0258 *
Age45-64                -2.8065     1.4646  -1.916   0.0573 .
MstatusMarried          -1.3167     2.1795  -0.604   0.5467
MstatusSingle           -1.8312     2.4320  -0.753   0.4527
MstatusWidow/ Widower   -4.3556     2.3559  -1.849   0.0665 .
educationPrimary        -0.1420     1.2090  -0.117   0.9067
educationSecondary       0.2051     1.2388   0.166   0.8687
educationTertiary        1.2899     1.4208   0.908   0.3654
OccupationEducationist  -0.1943     1.2555  -0.155   0.8772
OccupationFarmer         1.2276     0.8775   1.399   0.1639
Occupationother         -1.7614     1.0548  -1.670   0.0971 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 3.64 on 148 degrees of freedom
  (46 observations deleted due to missingness)
Multiple R-squared:  0.1306,    Adjusted R-squared:  0.04834
F-statistic: 1.588 on 14 and 148 DF,  p-value: 0.08874
```

```
> fit_utilizationsumsummary = summary(fit_utilizationsum)
> fit_utilizationsumsummary

Call:
lm(formula = utilizationsum ~ Sex + Age + Mstatus + education +
    Occupation, data = eliteTemite)

Residuals:
    Min      1Q  Median      3Q     Max
-16.330  -4.237  -1.090   4.628  15.536

Coefficients:
                       Estimate Std. Error t value Pr(>|t|)
(Intercept)             9.74550    4.75456   2.050  0.04219 *
SexMale                -0.03779    1.08112  -0.035  0.97217
Age1-14years           -1.76065    4.03928  -0.436  0.66357
Age15-24               -3.62763    2.96037  -1.225  0.22241
Age25-44               -2.38552    2.55697  -0.933  0.35240
Age45-64               -0.72010    2.49161  -0.289  0.77299
MstatusMarried          8.89732    3.71215   2.397  0.01781 *
MstatusSingle           5.78579    4.13809   1.398  0.16419
MstatusWidow/ Widower   6.86298    4.00255   1.715  0.08855 .
educationPrimary        0.79084    2.06427   0.383  0.70220
educationSecondary      0.75591    2.10823   0.359  0.72045
educationTertiary       7.44237    2.44588   3.043  0.00278 **
OccupationEducationist -2.20829    2.15143  -1.026  0.30640
OccupationFarmer        0.45377    1.47191   0.308  0.75830
Occupationother        -0.33183    1.84201  -0.180  0.85729
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 6.199 on 145 degrees of freedom
  (49 observations deleted due to missingness)
Multiple R-squared:  0.2387,    Adjusted R-squared:  0.1651
F-statistic: 3.247 on 14 and 145 DF,  p-value: 0.0001702
```

```
> feedmychicken.sex = xtabs(~ feedmychicken+ Sex, data=eliteTemite)
> feedmychicken.sex
                     Sex
feedmychicken         Female Male
                           7    7
  Agree                   58   36
  Disagree                17   17
  Neutral                 23   11
  Strongly Agree           6    4
  Strongly Disagree       15    8
> chisq.test(feedmychicken.sex)

        Pearson's Chi-squared test

data:  feedmychicken.sex
X-squared = 3.2034, df = 5, p-value = 0.6687
```

#Utilization purpose

```
> healthreasons.Occupation = xtabs(~ healthreasons+ Occupation, data=eliteTemite)
> healthreasons.Occupation
                  Occupation
healthreasons      Casual Laborer Educationist Farmer other
                                8            5     11    18
  Agree                        17            8     40    26
  Disagree                      6            3      7    10
  Neutral                       5            8      6     8
  Strongly Agree                0            2     13     3
  Strongly Disagree             1            0      2     2
> chisq.test(healthreasons.Occupation)

        Pearson's Chi-squared test

data:  healthreasons.Occupation
X-squared = 26.079, df = 15, p-value = 0.0372
```

#Abundance Variance

```
> typeofsoil.education = xtabs(~typeofsoil+ education, data=eliteTemite)
> addmargins(typeofsoil.education)
                   education
typeofsoil          None Primary Secondary Tertiary Sum
                       0       3         6        2  11
  Agree                3      27        38       29  97
  Disagree             4      10        14        1  29
  Neutral              5      17        10        5  37
  Strongly Agree       1       8         8       15  32
  Strongly Disagree    0       0         1        2   3
  Sum                 13      65        77       54 209
> chisq.test(typeofsoil.education)

        Pearson's Chi-squared test

data:  typeofsoil.education
X-squared = 33.546, df = 15, p-value = 0.003942
```