FOOD VALUE AND CONSUMER PREFERENCE OF TERMITES (Isoptera: Termitidae: *Pseudocanthotermes grandiceps*) IN WESTERN KENYA: COMPARISON WITH BEEF AND FISH

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DECLARATIONS

Declaration by the student

This thesis is my original work and has not been presented for a degree in any other University. No part of this thesis may be reproduced without my prior permission and/or University of Eldoret

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Declaration by the supervisors

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

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DEDICATION

This work is dedicated to all my brothers Paul, Abel, Joseph , Agaustin and Hezron , my sisters Beverlyne , Cathy , and Zippy , and lastly my mother, Betty for their encouragement and moral support throughout the study.

ABSTRACT

Kenya faces acute food shortages to satisfy the increasing population as traditional food stocks continue to be depleted as a result of environmental changes and increasing population. Faced with problems of food insecurity, increasing food prices and overreliance on the traditional food items, there is an urgent need for Kenyans to diversify their food sources. In western Kenya, the white ants have a long history of consumption as a delicacy during the rainy seasons. A major problem is that the white ants are varied in species and may not all contain the ingredients required by humans for nutrition. There are also very few studies that have attempted to evaluate the totality of white ants in Kenya. The aim of this study was to: (i) to determine the food value of the white ants in Western Kenya and (ii) to determine effects of preservation methods on the proximate composition of the white ants and (iii) to establish the consumer preferences for the white ants in various urban centers of Kenya. This was done with an overall aim of determining whether white ants can be declared as an alternative food source in Kenya. Data were collected and analyzed for proximate composition of moisture, protein, lipids, ash, crude fiber and nitrogen free extracts (NFE). Essential Amino Acid (EAA) profiles were evaluated to determine protein composition. The consumer preference and seasonal fluctuation was done through personal administered questionnaires that sought direct information on the issues of consuming white ants. Food value of the different species was analyzed by Analysis of Variance (ANOVA) while consumer preferences and effect of preservation methods on the proximate composition was analyzed by frequency distribution and cross-tabulations and hypothesis tested using chi-square. In all the analysis either a version of GenStat 4.0 S.E or SPSS 17.0 was used as appropriate. Results indicated that white ants have low levels of starch, 54% crude protein, 9.0% moisture, 10.8% ash, 9.5% crude fibre, which renders it a perfect substitute for beef and fish meals preferred by many households. The profile of Essential Amino Acid in the current study was found to be high and therefore white ants formed a very good source of essential amino acid to the local people. Under traditional and modern preservation methods, only sun drying resulted to loss of some nutrients, smoking only changed the texture while salting and freezing changed the moisture content and tastes. Frying and roasting improved the consumer appeal. Finally, many people had believed that white ants are additional food ingredients but should be considered an alternative food source to beef or fish. This study therefore concludes that white ants are suitable alternative food source to replace major protein food and nutritionists should start a campaign of making the white ants a delicacy. Given that white ants are neglected food in Kenya, it is recommended that the food items should be consumed as one of the food in the traditional diets in areas where the species occur.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Termites are social insects that belong to the order Isoptera, which means are winged and have been around on this planet for over 100 million years dating back to Mesozoic or late Paleozoic times (Pearce, 1997). Termites can be separated taxonomically using different features: external morphology, internal features, food and nest type, chemical and behavioral differences (Pearce, 1997). Wood and Johnson (1986) revised earlier works on classification of termites and classified known termite species into seven families, namely: Mastotermitidae, Kolotermitidae, Termopsidae, Hodotermitidae, Rhinotermitidae, Serritermitidae, and Temitidae. Termitidae being the largest family, 14 subfamilies, 280 genera and over 2600 species (Krishna, 1970; Pearce and Waite, 1994; Kambhampati and Eggleton, 2000; Eggleton, 2001, Ohkuma *et al*., 2004). These seven families may be divided into two main groups, the lower and ’higher termites’ depending on their mode of digestion. The first six families are collectively known as lower termites and rely on protozoan symbionts for digestion. Winged individuals (alates) have two pairs of wings, which are similar in size and shape.

Termites live in colonies consisting of a few thousands to several million individuals. Termites are a moderate sized insect order (c. 2600 described species) accepted to be an extremely important part of tropical and sub-tropical ecosystems (Eggleton, 1999). The tropical environment is known for its rich fauna and enormous population of termites, which are supposed to play an important role in the rapid turnover of organic matter in the ecosystem (Matsumoto, 1975). The seventh family, Termitidae, represents over 80% of all termite genera and 74% of all termite species (Wood and Johnson, 1986). Termitidae are often referred to as higher termites because of their advanced social behavior (Bignell *et al*., 1983). Their major characteristics are lack of symbiotic intestinal protozoa, large colonies (100,000 to millions) and the presence of a worker caste that has completed its development workers do not further develop into reproductive individuals or soldiers.

Because of its location in the tropics and climate (Sands, 1977a), Kenya, like most of the tropical environment possesses one of the most diverse biota in the world. Genetic analyses of a small number of non reproductive castes can provide much information concerning the breeding system of termite colonies (Clement, 1981; Reilly, 1987; Luykx, 1993) and, where certain questions are concerned, circumvent the need for destructive sampling. Monogamous breeding systems are, for example, easily identified through allozyme analysis as they yield predictable Mendelian genotypic frequencies. This approach additionally permits study of the temporal stability of the genetic composition of colonies and is especially useful where species have particularly fragile (e.g. Kalotermitidae) or diffuse (e.g. Mastotermitidae, Rhinotermitidae) nesting habits which make direct monitoring difficult. Prior work on the genetic structure of termite colonies has been limited (Clement, 1981; Reilly, 1987; Korman and Pashley, 1991; Luykx, 1993; Strong and Grace, 1993), despite the possible role that relatedness may have in promoting the maintenance of isopteran eusociality (Shellman-Reeve, 1997). Genetic studies have, however, provided key insights into levels of relatedness within colonies (Reilly, 1987) and have demonstrated geographical variation in mating systems of some species (Clement, 1981). Additional studies of the genetic structure of isopteran colonies seem likely to aid in the understanding of eusocial breeding system diversity (Crozier, 1980; Roisin, 1993), in the same way that similar work has contributed to the knowledge of hymenopteran eusociality (e.g. Pamilo and Varvio-Aho, 1979; Berkelhamer, 1984).

The highly derived genus Nasutitermes is taxonomically diverse with over 180 species (Krishna, 1970) and broadly distributed, being found in six of the eight major biogeographical regions (Pearce and Waite, 1994). Species in this genus have been relatively well-studied and are known to derive supplementary or replacement reproductives from alates (Thorne, 1985; Roisin and Pasteels, 1986a, b), nymphs (Gay and Calaby, 1970; Fontes and Terra, 1981) and workers (Noirot, 1985a; Noirot and Thorne, 1988; Miura and Matsumoto, 1996), and the number of functional queens and kings can, in some cases, range from one to many hundreds (Roisin and Pasteels, 1986b). White ants have been historically consumed in many parts of the world for time immemorial. Its delicacy is well known to many people in Kenya (Onyonka, 2001) and its abundance is unquestionable.

It is apparent in Kenya that there is problem of food insecurity, which has been a major issue that the government has been addressing. The population growth rate in Kenya is increasing at a rate of 6%. Historically, Kenya has relied intensely on agriculture to support more than 70% of her population. In the 1970s, sustained growth of agriculture above 10% per annum coupled with favorable weather patterns, witnessed unrivalled increase in Kenya's GDP by over 7% annually and therefore, the momentous economic growth was sustained, reducing food insecurity problems.

Currently, the country continues to rely heavily on agriculture as an engine to drive most of its economic growth, provide food, employment and most of the basic needs required by the populace despite the myriads of problems that has continued to duck the sector (Odeny, 2006).

However, in Kenya for quite some time now, food insecurity situation has been appalling because of frequent problems of unpredictable weather conditions as well as erratic and intermittent rainfall partly attributed to wanton dynamism in environmental conditions and poor agricultural policies put in place (Waiganjo *et al*., 2006; Were *et al*., 2008). With the liberalization of trade and introduction of structural adjustment programmes (SAPS), fertilizer costs have increased to a level unaffordable to small-scale farmers. Rather than rely on agriculture to wholly engineer the economic growth other sources of foods need to be considered. In an effort to bridge the food gap that ails the country, several food sources have been evaluated. Many of these protein food sources have been based on meat and beef products and by-products. They include animal protein sources such as chicken, beef, burgers, duck, turkey, pig meals among others as well as plant protein sources such as peas, beans, French beans, soybean etc. Whereas they have been providing protein sources for a long time now, they are increasingly becoming expensive and out of reach for many people. Furthermore, livestock are prone to diseases and drought as well as lack of pasture not to mention the constant conflicts that are associated with rearing large heard of cattle. Thus new ways of enhancing protein sources are required to avert the foreseen problem of food insecurity.

To meet these criterions, these diets must however, meet the nutritional requirement and should be readily accepted by the people whom they are intended for (Gatlin *et al*., 2007). Therefore, there is a need of finding such food that have the proximate composition to satisfy the demand of the general population.

1.2 Statement of the problem.

Kenya depends on agriculture to satisfy its food demands. In recent years there have been foreseen and unpredictable weather changes that have exposed the people to poor harvest and declining yields from agriculture. There is therefore the grave danger of chronic and sometimes acute food shortage that is likely to affect the nutritional and health status of the people. To reduce the chronic food shortages in Kenya, variety of food sources are required white ants being one of them. However, the nutritional composition of the white ants that would render it suitable as a food source has not been fully exploited.

1.3 Justification

Results of the current study will influence consumption of white ants in Kenya and will reduce chronic food shortages in the country. The several species collected will help the nutritionists in determining, the most suitable ants to be used by humans as food.

Since traditional food preservation methods are still in use in Kenya, it would be of little relevance to study to the use of modern methods since they are not extensively used in Kenya. The potential of their implementation can however be studied. This research will add to the knowledge of the preservation methods that have been affecting human food. The status of the quality of the human food available to consumers in the markets is of great importance because it gives a display of the nutritive value of the food received by consumers in this region of study.

Finally, Kenyans are not very adaptable to various sources of foods and therefore would not easily accept any food item in their diets. However, determining their response to a particular food items would likely reduce their resistance to change to a particular food item once put on the table.

1.4 Objectives

1.4.1 Main objectives

The aim of this study was to determine whether white ants can be used as an alternative food to beef and fish to reduce food insecurity.

1.4.2 Specific objectives

The specific objectives of the study were:

To determine the proximate composition of white ants used as food in Western Kenya

To establish the consumer preferences for the white ants in western Kenya.

To determine effects of preservation methods on the proximate composition of the white ants in urban centers of Kenya

1.5 Hypothesis

The proximate composition of white ants from Western Kenya does not render the insects as food.

The consumers have no preferences for white ants as alternative food source.

The preservation methods have no effects on proximate composition of the white ants in urban centers of Kenya

1.6 Scope of the study

The study was limited in scope geographically to Western Province and West Pokot where the white ants are consumed as food item. In its content the study was limited to the nutrient content and effects of preservation methods on the proximate composition of the white ants and further limited in time scope to four months of study. The results are however, expected to be applicable where similar species of white ants are found.

1.7 Limitation of the study

A limited number of respondents were selected, owing to financial constraints, and other logistical factors. Among the major limitations was unwillingness by a large pool of people to provide the information because many people have no access to the white ants.

CHAPTER TWO

LITERATURE REVIEW

2.1 Taxonomy of the white

Termites are well known both for their destruction of human property and for their construction of huge mounds or 'termitaria' which allow them to have a great degree of control over the temperature and humidity of the environment they live in. They are common in the tropics and occur in most warm habitats as well (Wilson, 1971). They are often called 'white ants' because the majority of them are white and small and live in large colonies. The most primitive termite known is Mastotermes darwiniensis from northern Australia. *Mastotermes darwiniensis* lives in the soil in nests consisting of up to 1 million individuals, will eat almost anything and has been described as the most destructive insect in Northern Australia, its workers are very similar to nymphs of the Cockroach *Cryptocercus punctulatus* (Ratcliffe *et al*., 1992). Some of the most advanced species are the Macrotermitinae which grow fungi for food (Termitomyces) inside their nests on piles of faecal pellets. The oldest known termites are fossils of *Cretotermes carpenteri* from the Cretaceous. The sterile workers live for 2-4 years while primary sexuals live for at least 20 and perhaps 50 years (http://www.earthlife.net/insects/isoptera.html).

Taxonomy provides a framework that enables us to undertake studies regarding the relationships between living things (phylogenic studies), so that we are better able to understand evolutionary processes, assess biodiversity and more efficiently manage it. Biological classification has a hierarchy of eight major taxonomic ranks based on original works of Carl Linnaeus (1707-1778), who grouped all known species according to similarities and physical characteristics. As technology advanced - Molecular Phylogenetics, which uses DNA sequences as data, augmented the original works of Linnaeus to improve classification conformity with Darwin's Principle of Common Descent (Eggleton, 1995). Today's combination of biological classification and phylogenetics belongs to the science of biological systematics. Myrmecologists - those who study ants, utilize taxonomic rankings to understand ancestral and evolutional relationships, biodiversity, and how organisms are related to, or different from, other similar organisms. The Biological Classification of Ants (Formicidae), from the general to more specific taxonomic rankings, looks like this:

Kingdom:	Animalia
Phylum:	Arthropoda
Subphylum:	Hexapoda
Class:	Insecta
Subclass:	Pterygota
Infraclass:	Neoptera
Order:	Hymenoptera
Suborder:	Apocrita
Infraorder:	Aculeata
Superfamily:	Vespoidea
Family:	Formicidae
Genus:	(there are many)
Species:	(there are many)

(Source: Pearce and Waite, 1994)

The white ants are descendents from wasp-like ancestors. That is why their Family "Formicidae" is classified under the Order: Hymenoptera, the same order under which bees are classified. The word, "Hymenoptera", derived from the ancient Greek word "humenopteros", literally means "membranous wings". The higher taxonomy of the termites is well worked out and fairly straight forward with over 75% of the known species being grouped into only one family the Termitidae, the first three families are the lower or primitive Termites and the last four are the higher or advanced termites (Snynder, 1989).

Order = Isoptera

Family = Mastotermitidae (contains only one species Mastotermes darwiniensis)

Family = Kalotermitidae (contains about 250 species)

Family = Termopsidae (contains 15 species)

Family = Hodotermitidae (3 genera, 19 species)

Family = Rhinotermitidae (14 genera , 343 species)

Family = Serritermitidae (contains only one species Serritermes serrifer)

Family = Termitidae (236 genera, 1958 species)

2.2 Life cycle and life of white ants

The eggs of white ants are normally laid singly but in the primitive Mastotermes the eggs are laid in double rows of 16 to 24 eggs glued together by a gelatinous secretion (Armitage *et al*., 1995). Incubation takes from 24 to 90 days and the eggs overwinter in cooler climates. There are normally seven nymphal instars in established colonies but the number varies according to a number of parameters such as temperature, age of colony, size of colony and relative humidity. Colony foundation is either by emission of swarms of sexuals, and/or budding (as in Reticulitermes lucifugus when the farthest outreaches of the colony develop secondary sexuals because of dilution of the inhibitory hormones). Swarms usually occur on hot still dry days, the sexuals tend to be weak fliers and 500 metres is a good flight, the swarm breaks up as the sexuals spread out. The sexuals cast off their wings as soon as they hit the ground. The females then either stand still or emit a pheromone to attract males (Kings) or run around all over the place until they meet one (Howse, 1970; Hegh, 1992). Courtship involves the male making some advances towards the female who strikes at him with her head this is followed by mutual antennal caressing and then followed by the male making more advances and the female striking at him with her head again followed by more mutual antennal caressing, this cycle may go round 4 or 5 times before the female makes up her mind whether or not to accept the male. If she does she runs away with him in close contact behind her this is called 'tandem running'. When they find a place to mate the King and Queen become very repelled by light and attracted by wood, when they find a suitable piece they take turns excavating a tunnel with a nuptial chamber at the end then seal themselves inside and begin making the nest (Kambhampati and Eggleton, 2000). At first the Queen lays about five eggs which are looked after by her and the King. When these hatch they are at first fed by regurgitation by the Queen but are soon munching wood and thus enlarging the nest. After 2 years the new nest may still contain as little as 10 workers and one soldier, soldiers take about a year to mature. After a few more years the nest begins to release sexuals.

Most primitive termites live in dead wood, their homes are just the tunnels created while they are acquiring food, and their nests have no real structure. Species of Rhinotermes, Reticulotermes and Captotermes are what is known as 'Subterranean

2.3 Geographical distribution

Termite density and the number of termite species increase as one move towards the equator. Termite distribution can be related to temperature and rainfall. Their distribution lies between a latitude of 450 and 500 in the north and south respectively .Termites have been found in all types of soils except in semi permanently water logged areas and in certain deep cracking vertisols (Wood, 1988) .The diversity of termites increases close to the equator and at and at lower altitudes ,except in Australia where equal numbers of termite species both north and south of the tropic of Capricorn (wood and sands ,1977).The macrotermitinae are found mainly in the middle east and Asia and include several important pest genera (Pearce ,1997). They are absent in Central America and Australia (Pearce, 1997)

2.4 Biology and ecology of *M. subhyalinus rambur (Isoptera: termitidea)*

Marotermes subhyalinus belong to the higher termite family and to the sub family macrotermitinae. *Marotermes subhyalinus* is morphologically very similar to M. michaelseni (Bagine *et al*., 1989). According to Bagine *et al*. (1994) the taxonomic status of *M. subhyalinus* and *M. michaeseni* has not yet been fully resolved, with open mounds being attributed to *M. subhyalinus* and closed mounds to *M. michaelseni*. Attempts have been made to discriminate between individuals from the two species by analyzing epicuticular hydrocarbons from workers and through electrophoretic analysis of macerated fresh soldiers (Bagine *et al*., 1989, 1994). Macrotermitinae cultivate fungus gardens of the Basidiomicete termitomices species. In a comb like structure in the center of their nest (sands, 1956). The food consumed by the workers passes through the gut relatively unchanged and is used for the construction of a fungus comb on which termitomyces species are grown .Its suspected that the first foraging workers of a colony in most of the macrotermitinae, including *M. subhyalinus* carry basidiospores of termitomyces spp. into the nest. Thomas (1981) , Abokhatwa (1977) has shown that termitomyces species degrades nitrogen poor and consequently provides termites with a relatively nitrogen rich food .The fungus comb consists of previously only partly digested food and when ingested by termites again ,further digestion occurs in the gut by enzymes such as cellulose and β–glucosidase produced partly by the ingested fungus and partly by the midgut epithelium and salivary glands of then termites themselves (Wood and Thomas, 1989).

As in most termite species of the macrotermitinae, the M. subhyalinus contain more than 80% larvae and out of the 20% adults 55-89% are workers and 11-44% are soldiers, while mature nests have more than 74% adults which consist of 74-94% workers and 3-25 % soldiers (Darlington, 1984b). The weight of the queen and the fungus comb in mature nests is almost 8 and 12 times higher, respectively, compared to young nests (Darlington, 1984b). Minor workers are responsible for feeding and tending the immature and reproductive, while foraging is done by major workers (Darlington, 1984b; Pearce, 1997).

In western Ethiopia, swarming of alates of *M. subhyalinus* occurs at the beginning of the rainy season between March and early June, always from 7:00 to 7:30 pm (Abdurahman, 1990). According to A Abdurrahman (1990) *M subhyalinus* forages throughout the year and after rains close to the nest. Only during the dry season, between December and March, their activity extends to areas further away from the nest. *Marotermes subhyalinus* builds dome shaped epigeous mounds with a density ranging from 10-12 mounds per hectare in western Ethiopia (Abdurahman, 1990). The density of macrotermes species mounds reported per hectare in the region ranged between 2-3 (sands, 1976b) and (Sanna, 1973). In Kajiado Kenya, 8.5 and 9 mounds per ha. were recorded for *M. subhyalinus* and *M. michaelseni*, respectively(Pomero, 1983).

2.5 Economic significance

Termites are eaten in many parts of the world. Termites are rich in calories and a very good source of proteins (Pearce, 1997). The mushrooms growing out of termite mounds are also consumed by many. Termites affect the soil profile by disturbing it and by redistributing the organic matter (Lee and Wood, 1971). As there are few earthworms in Africa, termites are very important in recycling and regenerating the soil matter (Pearce, 1997). Lee et al. (2003) studied the interactions between termite activity and soil characteristics Kenya and concluded that, 30-70% of the litter on the fields is removed by termites. However, return of the nutrients to the soil is obstructed since most of the litter removed is used by the termites themselves for constructing the fungus combs. The part of the nutrients which are added to the soil in the form of saliva and faeces during the construction of mounds and sheetings, and which ultimately enriches the topsoil, is small in comparison with the average uptake of nutrients by annual crops. Keller (2010) further stated that the excavation of tunnels by termites mainly enhances the aeration and rootability of the soil; the formation of the soil matrix composed of pellets appears to determine its moisture characteristics and its aggregated structure. Termites may be important in reclamation of landfill sites, and areas where large amount of rubbish have been deposited.

Termites are generally grouped according to their feeding behavior. Thus, the commonly used general groupings are subterranean, soil-feeding, dry wood, damp wood, and grass-eating. Of these, subterraneans and dry woods are primarily responsible for damage to human-made structures. All termites eat cellulose in its various forms as plant fibre. Cellulose is a rich energy source (as demonstrated by the amount of energy released when wood is burned), but remains difficult to digest. Termites rely primarily upon symbiotic protozoa (metamonads) such as Trichonympha, and other microbes in their gut to digest the cellulose for them and absorb the end products for their own use. Gut protozoa, such as Trichonympha, in turn rely on symbiotic bacteria embedded on their surfaces to produce some of the necessary digestive enzymes. This relationship is one of the finest examples of mutualism among animals.

Most so called "higher termites", especially in the Family Termitidae, can produce their own cellulase enzymes. However, they still retain a rich gut fauna and primarily rely upon the bacteria. Due to closely related bacterial species, it is strongly presumed that the termites' gut flora are descended from the gut flora of the ancestral wood-eating cockroaches, like those of the genus Cryptocercus.

Some species of termite practice fungiculture. They maintain a 'garden' of specialized fungi of genus Termitomyces, which are nourished by the excrement of the insects. When the fungi are eaten, their spores pass undamaged through the intestines of the termites to complete the cycle by germinating in the fresh faecal pellets (Clarke, 1993; Clarke, 1994). They are also well known for eating smaller insects in a last resort environment.

In many cultures, termites are used for food (particularly the alates). The alates are nutritious, having a good store of fat and protein, and are palatable in most species with a nutty flavour when cooked. They are easily gathered at the beginning of the rainy season in West, Central and Southern Africa when they swarm, as they are attracted to lights and can be gathered up when they land on nets put up around a lamp. The wings are shed and can be removed by a technique similar to winnowing. They are best gently roasted on a hot plate or lightly fried until slightly crisp; oil is not usually needed since their bodies are naturally high in oil. Traditionally they make a welcome treat at the beginning of the rainy season when livestock is lean, new crops have not yet produced food, and stored produce from the previous growing season is running low (Fladung,1924). They are also eaten in Indonesia, including Central Java, where they are roasted or fried

Odhiambo (1978) mentions several kinds of insects used as food in Kenya: The long-horned grasshopper, `nsenene', is an important item of diet in certain parts of Uganda and Kenya, as recent swarms in many parts of East Africa have shown this year. Lake flies are collected by many ethnic groups living around Lake Victoria and the great lakes along the Western branch of the Rift Valley; and these are made into large balls marketed in rural market-places, thus providing an important source of animal protein. Termites when in flight are collected throughout most of Africa as a sort of snack, but in some places, especially in the semi-arid savannah zones, termites do indeed provide an essential element of the diet among the non-livestock keeping groups.

The Elgeyo live principally on the grain they grow and on the milk, blood and meat provided by their livestock, i.e., cattle, sheep and goats. Stock is practically the only form of wealth recognized or desired. Massam states that white ants and honey are distinctly luxury foods to the natives and that honey is "especially esteemed when eaten with pounded 'white ants.'" At lower elevations, termite mounds may be 20 feet high and, at the beginning of the rains, termites are an important part of the Elgeyo food supply. They are harvested soon after the rains begin by digging a hole near the base of the mound, then knocking the mound over and lighting a fire near the hole. The emerging winged termites are stupefied by the smoke and fall into the hole, from which they are scooped and stuffed into leather bags to suffocate. They are then dried in the sun, the wings are removed, and the bodies pounded into a paste which is either eaten alone or with honey. Massam states that it is a very fattening food.

At elevations of about 6,000 feet the termites are smaller and do not build tall mounds. They are harvested differently. A hole is dug about 9 inches in diameter and 9 inches deep, about a yard from where the termites are expected to emerge. It is lined with smooth, neatly overlapping leaves. A piece of hide, to exclude the sunlight, is supported by twigs from the termite exit hole to the pit that has been dug. The emerging sexuals, unable at first to use their wings, crawl toward the light at the end of the hide-covered tunnel and fall into the pit, from which they are unable to escape because of the smooth leaf lining. They are gathered in bags and taken away to dry. Termites from yet higher elevations are not collected as they are very small and said to be bitter. Massam notes that these day-flying termites can emerge in clouds on sunny days following heavy rain and are a great nuisance by their numbers. He noted also that they were attracted more to dark-blue jerseys than to lighter khaki.

Ominde's (1988) African Cookery Book offers authentic African recipes representing a cross-section of East African cuisines -- Kenyan, Tanzanian and Ugandan. It includes recipes for insects eaten as delicacies, such as fried white ants and fried grasshoppers and locusts. It is indicative of the revival of interest in food insects in Africa that the The Research and Development Forum for Science-Led Development in Africa (RANDFORUM) held an Africa-wide Exhibition on Indigenous Food Technologies in Nairobi, Kenya, December 13-17, 1995 (The Food Insects Newsletter, 1995). This was part of the larger Exhibition on Innovative Technologies for Food Production and Processing that are Commercializable. Under the aegis of a center for indigenous knowledge, the exhibition included a food fair as well as displays of living insects in their natural habitats and the processed end-products ready for consumption. Posters and diagrams provided information and there was a one-day symposium on the subject. According to Hollis (1905: 318), among the Masai, "old men eat the [honey] comb full of grubs

Bryk (1927; vide Bodenheimer 1951: 151-152) states that the swarming sexuals of Odontotermes are caught in almost unbelievable quantities and are an important food in the Mt. Elgon region where several methods are used for harvesting them. Both winged and wingless forms are collected and they are eaten either raw or roasted, although Bryk himself thought the taste was insipid. Although the big harvest begins with the onset of the rains and swarming of the sexuals, some termites could be induced to emerge early by beating sticks together to simulate the sound of rain and by pouring water down the ernergence holes to strengthen the impression of rain. Bryk notes that only a small proportion of the emerging termites are captured; many become the prey of birds.

Karp and Karp (1977) describe the dietary staples, meal patterns, and the meaning of food in Iteso culture. The Iteso are an Eastern Nilotic-speaking people who live in the northern part of Busia district in the Western Province of Kenya. There are about 250,000 Iteso in Kenya and about 500,000 in Uganda. The authors mention the use of termites as a snack food (p. 105):

2.6 Component of food in the diet

In human, nothing is more important than sound nutrition and adequate food. If the food is not consumed by the human or if the human are unable to utilize the food because of some nutrient deficiency, then there will be no growth. An undernourished person cannot maintain his health and be productive, regardless of the quality of the environment.

The production of nutritionally balanced diets for human requires efforts in research, quality control, and biological evaluation. Faulty nutrition obviously impairs human productivity and results in a deterioration of health until recognizable diseases ensue (Kraak, 2004). The borderlines between reduced growth and diminished health, on the one hand, and overt disease, on the other, are very difficult to define. There is no doubt that as our knowledge advances, the nature of the departures from normality will be more easily explained and corrected. However, the problem of recognizing a deterioration of performance in its initial stages and taking corrective action will remain an essential part of the skill in nutrition.

2.6.1 Protein requirements

Protein is the most important component of the diet of human because protein intake generally determines growth (protein growth has, in general, priority), has a high cost per unit and high levels are required per unit of foods (Gatlin et al., 2007). Protein is required in the diet to provide indispensable amino acids and nitrogen for synthesis of non-indispensable amino acids. Protein in body tissues incorporates about 23 amino acids and among these, 10 amino acids must be supplied in the diet since human cannot synthesise them (Roberts, 1996). Amino acids are needed for maintenance, growth, reproduction and repletion of tissues. A large proportion of the amino acid consumed by a human are catabolized for energy and human are well-adapted to using an excess protein this way. Catabolism of protein leads to the release of ammonia (Boyd, 1992).

First observations on human protein and amino acid requirements came from studies on natural population. Natural diet including beef, fish and some insects is generally rich in protein and has a good amino acid balance (Nowak, 2006). All dietary proteins are not identical in their nutritive value. The nutritional value of a protein source is a function of its digestibility and amino acid makeup. A deficiency of indispensable amino acid creates poor utilization of dietary protein and hence growth retardation, poor live weight gain, and food efficiency (Cherop et al., 2009).

In severe cases, deficiency reduces the ability to resist diseases and lowers the effectiveness of the immune response mechanism. For example, experiments have shown that tryptophan-deficient human become scoliotic and methionine deficiency produces lens cataracts (Tacon, 1998). Most fish generally contain 35-45% digestible protein (DP), or 40-50% crude protein. However, amino acids or protein must be supplied in relation to digestible energy (DE). Increasing these proportions increases ammonia excretion; the requirement for dissolved oxygen is also increased because the efficiency with which the energy is used is decreased.

The main reasons why there are higher protein requirement is because; the protein requirement in terms of dietary concentration (% of diet) is high but the absolute requirement isn't (g/kg body weight gain). This is due to the fact that human have a lower absolute energy requirement than other mammals. This results in similar body weight gain/g protein ingested as mammal but better food efficiency (gain: food). Secondly, protein (amino acids) is used as a major energy source. Some economy can be made here if other dietary fuels are present in adequate amounts, e.g. increasing the lipid (fat) content of diet can help reduce dietary protein (amino acid) catabolism and requirement. This is referred to as protein-sparing effect of lipids (Gatlin et al., 2007). Protein to useful energy ratio is the factor that should be considered, not % protein of the diet per se.

2.6.2. Lipids (Fats)

Lipids (fats) encompass a large variety of compounds. Lipids have many roles: energy supply, structure, precursors to many reactive substances, etc. In the diet, lipids are most commonly found as triglycerides, phospholipids and, sometimes, wax esters (Patrick, 2008). Triglycerides are composed of a glycerol molecule to which three fatty acids are attached. Phospholipids are also composed of a glycerol molecule but with only two fatty acids. Instead of a third fatty acid a phosphoric acid and another type of molecule (choline, inositol, etc.) are attached (Manchini, 2003). Wax esters are made of a fatty acid and a long chain alcohol and are a common form of lipid storage. The main role of triglycerides is in the storage of lipids (fatty acids). Phospholipids are responsible for the structure of cell membranes (lipid bi-layer). Fatty acids are the main active components of dietary lipids. Human are unable to synthesize fatty acids with unsaturation in the n-3 or n-6 positions yet these types of fatty acids are essential for many functions (Robert, 1998). These two types of fatty acids are, therefore, essential for the person and must be supplied in the diet.

Deficiency in essential fatty acid result in general, in reduction of growth and a number of deficiency signs, including depigmentation, fin erosion, cardiac myopathy, fatty infiltration of liver, and "shock syndrome" (loss of consciousness for a few seconds following an acute stress). Human require about 0.5 to 1% long chain polyunsaturated n-3 fatty acids (EPA (20:5 n-3) and DHA (22:6 n-3)) in their diet. This amount is easily covered by ingredients of marine origins, such as human meal and human oil, which are always present in significant amounts in fish foods.

2.6.3 Carbohydrates

Carbohydrates represent a very large variety of molecules. The carbohydrate most commonly found in human food is starch, a polymer of glucose (Goby, 2005). Human have a poor ability to utilize carbohydrates as such methods of improving quality are available. Raw starch in grain and other plant products is generally poorly digested in their raw forms. Cooking of the starch during pelleting or extrusion, however, greatly improves its digestibility. However, even if the starch is digestible, human only appear to be able to utilize a small amount effectively. Carbohydrates only represent a minor source of energy for humans. A certain amount of starch or other carbohydrates (e.g. lactose, hemicellulose) is, nevertheless, required to achieve proper physical characteristic of the food.

2.6.4 Vitamins

The vitamins are generally defined as dietary essential organic compounds, required only in minute amounts, and which play a catalytic role and but no major structural role. So far, 4 fat-soluble and 11 water-soluble vitamins or vitamin-like compounds have been shown to be essential to humans. Requirement is generally measured in young fast growing humans. However, requirements may depend on the intake of other nutrients, size of the humans, and environmental stress. Many symptoms of vitamin deficiency are non-specific.

It is also tedious and expensive to analyze diets for vitamins. Therefore, diagnostic of vitamin deficiencies is often difficult. Nutritional disorders caused by vitamin deficiencies can impair utilization of other nutrients, impair the health of humans, and finally lead to disease or deformities (Gatlin et al., 2007). Nutritional deficiencies signs usually develop gradually, not spontaneously. However, the culturist may obtain clues of deficiency indirectly through low food intake and poor live weight and food efficiency.

2.7 Consumer acceptability

It would be inconclusive to adduce that there is low preference for indigenous foods considering the lack of reasonable data in Kenya. The reason therefore that could explain the present controversy in the pool of available literature findings lies in the availability of the lower diversity of traditional food items in many regions of the country.

Seasonality of the agricultural products is a widely researched phenomenon and has been accredited by Tomek and Robinson (2006) to radically alter the production cycles results to shortages at time of dry seasons and bumper harvest leading to oversupply during the rainy seasons, which partly explains the observed dynamics of traditional food preferences.

There are several plausible reasons for making preference on commodity over the other. This has been practiced by many consumers and in essence affecting the sellers stocking preferences. Indigenous food items are often preferred in line with pricing and nutritional aspects of it though preferential liking for the some traditional food items can also be due to medical roles. Price differential is a factor that contributes more towards commodity preferences than any other product's factors. Since the indigenous foods have, generally elastic demands (Kanyi, 2007), because of presence of variable number of substitutes, they are bound to attract many consumers when there is a slight changes in market pricing of other substitutes. Reports of preference of particular products when market price change has been reported elsewhere in many parts of Kenya for chicken when the price of meat changes.

Though many people have particular preference for indigenous foods, there are generally many qualities that particularly endear them to consume particular commodities. Most consumers of indigenous foods have particular quality likings that make them be attracted to the food items. For many food items, quality preferred by the local consumers emanates from cultural, nutritional and medicinal values. This is particularly true considering that many eons of cultural polymorphism strived towards consumption of the traditional food items as a cultural regalia and thus most people have respects for cultural norms. As much as it is easy to consume the indigenous white ants as a cultural obligation, they find preparation of the white ants to be quite easy and as such, many people have particular tastes for the food.

Particular preferences of food items have particular dislikes that make their consumption to be particularly limited to a wide range of people. It has been reported that many indigenous foods are more preferred due to culture. Spot check by Odero (2000) in Kisumu established that even though majority of people like consuming the indigenous foods, almost all the consumers reported that they find it difficult to prepare and eventually to cook them.

The importance attached to traditional food items' consumption depends on the community in question. The species used as food the value of each species to the community and the wealth of indigenous knowledge varies a great deal as well. The review of the available literature indicates that traditional food items are useful as alternative food sources. Yet, their nutritional composition would dictate that they be used as main food sources. Research in Kenya is out rightly lacking and therefore, there is very little information known about the importance of white ants as food source. The current study intends to bridge that gap.

2.8 Food insecurity

According to FAO (1996), food security exists when all people at all times have physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for an active healthy life. Food security programs usually address one or a combination of these three components:

Food availability: When adequate quantities of food, supplied through a combination of household production, commercial imports, or food assistance are consistently available to all persons in a country annually.

Food access: When all members of a household have adequate resources to secure culturally acceptable food for a nutritious diet; this depends on the income available to and distributed within a household as well as affordability of local food.

Food utilization: When food is prepared and consumed to maximize its value for all family members, which relies upon the knowledge and behaviors within a household concerning food storage and processing, basic nutrition principles, and proper child care.

According to Tayler (1997), there are three types of food insecurity: chronic when there is inadequate access to food on a regular and repetitive basis; seasonal or cyclical (appearing at predictable times of the year); and transitory or temporary (resulting from shocks and natural disasters). The primary causes of food insecurity in Kenya are poverty, low agricultural productivity, conflict, HIV/AIDS and the occasional natural disaster (droughts ,floods) (Nyaberi and Wandiga ,2001) Poor food utilization, particularly as it relates to the nutrition is also a food security issue. All of these causes except the natural disasters are chronic situations. Resolving problems of chronic food insecurity require development solutions, not temporally food relief. Food relief may be required to prevent famine, but it largely treats the symptoms, not the causes of food security.

Crude estimates indicate that production per capita of basic food is about 856kg or 80kg per capita per year more than the approximately 776kg per capita per year required to constitute the basic crop portion of the food basket used to establish the food poverty line (FAO,2001). Production of livestock and personal products has had an upward trend during the decade, implying that they also are sufficient to make up the remaining portion of the food basket. Typically Kenya produces enough food to supply its population with their minimum calculated food and energy requirements although the same cannot be said for the whole regions (Ogonda, 2003). In terms of basic food crop production, the central region has the lowest production per capita but, by most reports, is the best fed .The central region focus on cash crops and expansion into high -value specialty crops for urban and export markets provide the regions rural population with incomes that are 24% above the national average for rural populations and the possibility of being relatively food secure.

Poverty in Kenya is predominantly rural phenomenon (Were *et al*., 2008). While only about 10%of the urban population fall below the poverty line, 39% of the rural population falls below that same measure (KHDS,2005). However, the portion of the rural population below the poverty line has fallen from 60% in 1992/93 to 39% in 1999/2000. Cash crop farmers have seen poverty rates decline much more rapidly than have non- crop (livestock) and food crop producers'. Analysis by Appleton (2000) indicates that the entire reduction in poverty in recent years is due to economic growth – more income, as opposed to the re-distribution of existing income. But it was difficult to sustain the present target of 7%per annum growth in GDP.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study area

3.1.1 Background and location

This study was carried out in Western Kenya covering Western Province, Nyanza Province and part of the North Rift (Figure 1). In presence of diverse livelihood mainly in the agricultural sector, close to 4 million people have settled in the region, attributable to employment prospects while others are in the district due to immigration. The study area is situated about 300-800 km North West of Kenyan capital, Nairobi. It lies at an average altitude that ranges between 1800-2600 meters above sea level. The area covers approximately 19200 km^2

3.1.2. Climate

Climate within the study area is strongly influenced by altitude and physical features such as escarpments and volcanic peaks mainly from the Cherangani Hills, to Kakamega forest and Mount Elgon. The area has a high variation in temperature ranging from 10.5 –25.5ºC within the year thus favoring growth of agricultural crops within the area. There is a bimodal rainfall; the mean being just over 1000 mm annually.

3.1.3 Populations and land tenure

The area has slightly over 4 million persons with a density of about 320 persons per square kilometer (KNBS, 2010). The number of households within the study area according to 2010 census is approximately 822,850. Land is under individual ownership and partly through cooperates such as the several forest farms spread along the breath of the area.

Figure 3.1: Map of Kenya showing the location of the study area (Source: Adapted and modified from Microsoft Encarta 2008)

3.1.4. Economic activities

The main human economic activities within the study area are agriculture through crop farming and livestock husbandry such as rearing cattle, sheep, goat and pigs. The main farming activities within the entire district include cultivation of cereals such as maize. Non-cereal crops cultivated include potatoes and a variety of crops in small plots. Horticulture, agro-forestry, forestry are also practiced.

3.2 Research Design

Food value of the white ants was done by proximate analysis of moisture content, nitrogen free extracts, crude protein, crude lipid, ash and crude fibers. Fatty acid profiles and amino acid profiles were also evaluated to determine the protein components. The consumer preference was done through personal administered questionnaires that sought direct information on the issues of consumer preference of the white ant species.

3.3.1 Collection of white ant samples

White ants were collected from various parts of Western Kenya during long rain periods when they are expected to be available. Colonies were marked and mapped, and 50% of the colonies were re-sampled during any time there was white ants. The selection of the sampling sites was guided by past experience and after interview with various stakeholders in the region who are expert in identification of areas where white ants predominate. Collection of the white ants was done using traps which were mounted on the termite mound to trap the alates. Collections were also made by breaking open the termite mound. Some of the alates and a number of small or large soldiers and workers were preserved (in 70-80% ethanol) for identification at the National museums of Kenya. Approximately 100 live individuals from each colony were Sun-dried after suffocating them in polythene bags. They were also stored in containers with tight lids. Collections did not discriminate between small or large workers, or soldiers.

3.3.2 Proximate analysis

The collected white ants were analyzed for proximate composition of crude protein (N_2×6.25), crude lipid content, moisture, and ash content using standard methods detailed in AOAC (1995). Dry Matter (DM) was determined by oven drying them at 110°C for 24 h. Crude protein (N ×6.25) was determined by Kjehdal method after acid digestion. Crude lipid was determined by the Soxhlet apparatus. Ash content was determined by incineration in a furnace at 550°C for 24 hrs. Crude fibre was determined by digestion with 1.25% H_2SO_4 and 1.25% NaOH solutions. Nitrogen Free Extracts (NFE) was calculated from the differences. Gross energy was calculated using conversion factors for protein, lipids and carbohydrates provided in Tacon (1998) and confirmed by adiabatic bomb calorimeter. Amino acid compositions of the white ants were determined by automated amino acid analyzer after hydrolyzing the sample for 24 h with 6 M HCl at 110˚C. Sulphur-containing amino acid was oxidized using performic acid before acid hydrolysis. All analyses were performed, in duplicate, on the sub samples of white ants.

3.4 Consumer preference data

3.4.1 Research design

Interviews and questionnaires were used to collect data through a cross-sectional survey. Such designs are often used for descriptive, explanatory and exploratory purposes (Labovitz and Hagedorn, 2006; Kothari, 2004). It was used to investigate the consumer acceptance of the white ants in the region.

3.4.2 Target population and sample size

The target population consisted of all the people who consume white ants. The number is estimated at 1,000, 000. Sample size was determined from the target population using the formula by Mugenda and Mugenda (1999) $n = z^2 (pq)/d^2$

n = the desired sample size

z = Standard normal deviation (at 95% = 1.96)

d = the acceptable range of error (0.05)

p = the proportion of people who consume white ants in Western Kenya (80%)

q = the proportion of people who do not consume white ants in Western Kenya (20%)

Based on the calculation, the sample size for this study consisted of 240 people from the study area. This number was deemed representative of the target population from each of the heterogeneous sub-groups within the area.

3.4.3 Sampling strategy

This study employed systematic sampling technique in combination with purposive sampling method to select the respondents for the interviews and those who will answer to the questionnaires. Currently, there are 45 administrative districts in the region. At least 5 people from each district were selected from areas where there are high densities of termites at random until the desired 240 respondents was obtained. The random sampling technique ensured a representative sample was selected on probabilistic criterion and thus allowing each person an equal chance of selection. Additional 10 key informants were included in the sample to provide desired information of the subject at hand.

3.4.4 Research tools and instruments

Questionnaires and interviews were used as the main tool for data collection. The selection of these tools was guided by the nature of the data to be collected, the time available as well as the objectives of the study. Since the research was concerned with views, opinions, perceptions and feelings, such information was best collected using questionnaires and interview schedule (Touliatos, 1998) since such variables cannot be directly observed. Semi-structured instruments questionnaires were used so that a balance between the quantity and quality of data was collected. Data were collected at designated times at household levels. Questionnaires were given to people who can read and write and they were given the opportunity to fill the questionnaires.

3.5 Data analysis

Qualitative data from the questionnaires and interviews collected during this study were analyzed by descriptive statistics employing tools of central tendencies, frequency distributions, cross tabulations and chi-square (χ^2) of goodness of fit tests using SPSS version 17.0. Chi-square test was suitable here since enabled the identification of any significant differences in the frequencies of the alternative response. All data was analyzed at a level of $p < 0.05$. After analysis, data were presented using table, bar graphs and pie charts. The median ingredient uptake volumes were calculated based on the respondents responses, which were then used to calculate the daily ingredient intake according to the formulas:

$$DI_{ingredient} = \sum_{i=1}^{n} C_{food} x I_{food}$$

$$I_{ingredient} = \frac{SS_{median} x FF_{food}}{30.4}$$

Where $DI_{ingredient}$: the daily intake of ingredient from food (µg/L)

C_{food}: the average metal concentration of the item (µg/L); I_{milk}: daily food intake (L/day); SS_{median}: the median quantity of the food item consumed (g/day); FF_{food}: food frequency i.e. the number of days in a month that the food was taken by the respondents (days/month). One month was assumed to be 30.4 day (365/12).

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter presents the results of the study relative to the objectives and hypothesis of the study. The chapter is divided into four sections. Section 4.2 presents information concerning the socio-economic backgrounds of the respondents. Section 4.3 provides analyzed information on the proximate composition of white ants used as food in Western Kenya. Section 4.4 provides information on the consumer preferences for the white ants in various urban centers of Kenya while section 4.5 summarizes the information on the effects of preservation methods on the proximate composition of the white ants in urban centers of Kenya.

4.2 Socio-economic Backgrounds of the Respondents

The socio-economic backgrounds of the respondents are shown in Table 4.1. The distribution in sex, levels of education and salary were significantly different among the respondents ($p < 0.05$) while age distributions among the respondents were not significantly different ($p > 0.05$). Many respondents were females, with secondary levels of education. Salary earned by most of the respondents was over Kshs. 1001-5000 per month.

Table 4.1: Socio-economic backgrounds of the Respondents

	Variables	Frequency	Percent
Age (Years)	< 25	28	11.7
	25-35	68	28.3
	36-45	72	30.0
	46-55	47	19.6
	> 55	25	10.4
	Total	240	100
Gender	Female	162	67.5
	Male	78	32.5
	Total	240	100
Levels of Education	None	21	8.8
	Primary	61	25.4
	Secondary	105	43.8
	College	47	19.6
	University	6	2.5
	Total	240	100
Income (Kshs.)	< 1,000	18	7.5
	1,000-5,000	97	40.4
	5,001-10,000	72	30.0
	10,001-20,000	45	18.7
	> 20,000	8	3.3
	Total	240	100

4.3 Proximate composition of white ants used as food in Western Kenya

The ingredient compositions and the profile of the essential amino acids (EAA in g/100 g feed) of the white ants when compared with two other protein diets commonly consumed by the local residents in the study are provided in Table 4.2. Moisture content was similar for all the three tested diets at about 10% of the body weight of the white ants. Protein content of the white ants was found to be 54% which was, significantly the lowest among the food items analyzed ($p < 0.05$). Crude lipid content of the white ants was about 9%, which was, significantly ($p < 0.05$) the highest when compared to the beef and fish by factor 4.5 ×. Ash content of the white ant ranged from 9.2 to 10.9%, but was found to be significantly ($p < 0.05$) the highest when compared to beef and fish. 8-10% of the ants, beef and fish were found to be crude fibres, but the differences were not significant ($p > 0.05$). The total content of carbohydrates was significantly higher in beef than ants and fish feeds ($p < 0.05$). Gross energy derived from consumption of 100 g of ants was 4.2 kcal, which was significantly ($p < 0.05$) the lowest than the gross energy derived from fish and beef. The profile of the amino acid of the white ants were also analyzed and based on the essential amino acid scores, EAA of the white ant was the lowest (24.5 g/100g) while that of fish was the highest. However, the profile of the EAA score as a percentage of the crude proteins in the feeds was similar for all the feeds at 46%.

Table 4.2: Proximate composition (g100 g^{-1}) of the white ant meal and two other common protein feeds with their amino acid profiles. Values are means ± SEM. Amino acids were not analyzed in triplicate.

	Food items			ANOVA	
Ingredients (% as fed basis)	White	Fish	Beef	F-	p-
Dry matter	90.2 ±	89.6 ±	90.21 ±	0.432	0.532
Crude protein	53.9 ±	66.9 ±	62.22 ±	5.42	0.004
Crude lipid	9.35 ±	5.54 ±	6.23 ±	9.785	0.000
Ash	10.81±	3.31 ±	3.30 ±	10.225	0.000
Crude fiber	9.53 ±	8.27 ±	10.24 ±	1.954	0.094
NFE	6.61 ±	5.58 ±	8.03 ±	3.963	0.013
Gross energy (kcal 100 g^{-1})	4.19 ±	4.53 ±	4.43 ±	1.562	0.234
Essential Amino acids (g					
Histidine	3.02	3.95	2.25		
Isoleucine	2.56	2.98	3.31		
Leucine	2.36	2.64	2.41		
Lysine	5.79	5.21	5.04		
Methionine	2.78	3.56	3.51		
Phenylalanine	4.01	5.39	4.92		
Threonine	2.64	4.01	4.22		
Valine	1.32	3.87	2.99		
Total EAA	24.5	30.6	28.6		
Ratio:EAA:CP	45.4	46.2	46.0		

Values for fish and beef adapted from Cherop *et al.*, 2009

The estimated median consumption of the of white ants was 0.15 g per day, beef was 0.11 g per day and fish was 0.08 g per day for the sampled population based on the food frequency questionnaires (FFQ). Based on the table 4.3, crude protein levels taken by the respondents per day was 80 g/100g in white ants and lowest in beef at 50 g/100g feed. Crude lipid uptake was also highest in white ants and lowest in beef. However, consumption of white ants provided more ash and crude fiber to the locals than fish and beef. Concerning the essential amino acid uptake, white ants provided the highest levels of all the essential amino acids compared to the fish and beef. However, except for lysine, none of the food(fish and beef) consumed provided the required daily intake of the EAA.

Table 4.3: The calculated average dietary intake (g/100 g/day) of the various ingredients and essential amino acids

Food items				
Ingredients (% as fed basis)	White	Fish	Beef	
Dry matter	135.30	98.56	72.17	
Crude protein	80.85	73.59	49.78	
Crude lipid	14.03	6.09	4.98	
Ash	16.22	3.64	2.79	
Crude fiber	14.30	9.10	8.19	
NFE	9.92	6.14	6.42	
Essential Amino acids (g				Requirements
Histidine	4.53	4.35	1.80	10
Isoleucine	3.84	3.28	2.65	20
Leucine	3.54	2.90	1.93	39
Lysine	8.69	5.73	4.03	4
Methionine	4.17	3.92	2.81	10
Phenylalanine	6.02	5.93	3.94	25
Threonine	3.96	4.41	3.38	15
Valine	1.98	4.26	2.39	26

4.4 Effects of preservation methods on the proximate composition of the white ants in urban centers of Kenya

The white ants were then subjected to common methods of preservation found in Kenya and the subsequent changes in the proximate composition analyzed. The results are presented in Table 4.4. Freezing was the only preservation method that increased moisture content in the white ants. Roasting and sundrying resulted to most significant increase in moisture loss in the white ants. On the other hand, freezing did not produce significant reduction in the protein content while roasting and sundrying resulted to most apparent loss of crude protein content in the white ants. Highest ash content was obtained in frozen product while lowest ash content occurred in sundried and roasted ants. Crude fibre content in the diet were enhanced by freezing while sundrying and roasting resulted to significant reduction in the crude fibre content in the white ant. Finally gross energy did not significantly change in all the preservation methods.

Table 4.4: Variation in the proximate composition of the white ants in various preservation media

Proximate composition	Normal	Sundried	Smoked	Salting	Freezing	Roasting
Dry matter	8.8^{d}	4.8^{b}	6.9^{c}	7.5^{c}	11.8^{e}	3.8^{a}
Crude protein	52^{d}	48.6^{b}	50^{c}	50.1c	52.1^{d}	44.5^{a}
Ash	9.4^{c}	7.1^{a}	9.4^{c}	8.3^{b}	9.8^{d}	7.3^{a}
Crude fibre	4.2^{c}	2.3^{a}	4.2^{c}	4.2^{c}	4.7^{d}	3.3^{b}
Gross energy (MJ Kg^{-1})	18.4	18.1	18.2	18.2	18.0	18.2

Mean values in each row with a common superscript letter are not significantly different from each other ($P > 0.05$).

4.5 Consumer preferences for the white ants in various urban centers of Kenya

To determine the consumer preference of the white ants, information concerning criteria of preference was used and reasons why consumers do not prefer other traditional food sources. The first survey identified that local consume beef, poultry, vegetables mainly traditional, cabbages, fish, and white ants. The consumers were asked to rank foods that should be considered a delicacy and should be advocated for all the Kenyan to take as long as they are available. The results are as shown in Figure 4.1. fish and beef ranked highest followed by white and brown ants respectively. Bacon and wild birds ranked lowest.

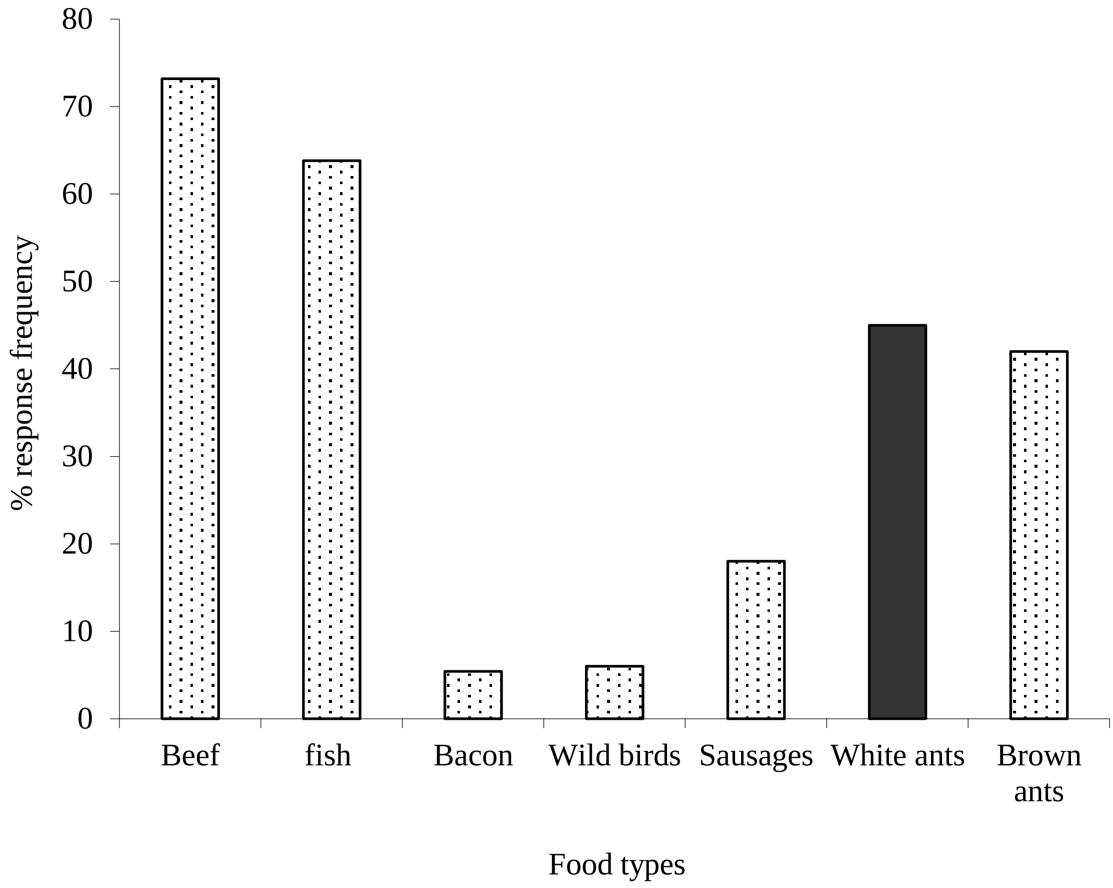

Figure 4.1: Preferences for various food items among the sampled respondents

Information was also sought why they prefer white ants over other sources of proteins. Information concerning the criteria used for ranking white ants among the consumers surveyed is as shown in Figure 4.2. Most consumers preferred white ants because of their cultural attachments (54.2%) followed by their nutritional contents (35.2%) while others believed that it is less costly than other food items. The least number believed that its medicinal values are likely to make it more preferable.

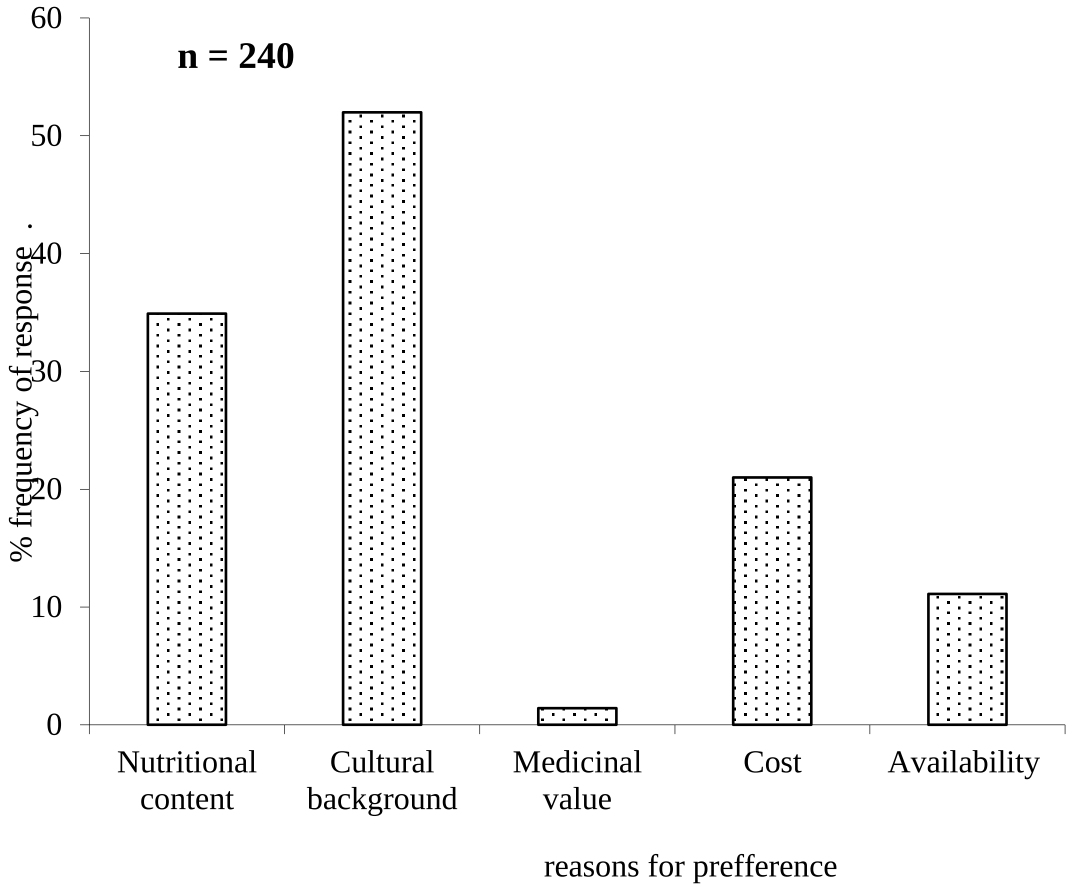

Figure 4.2: Criteria used to rank the white ant as food sources

Further information on why consumers do not prefer ‘traditional protein’ including white ants is shown in Table 4.5. The main reasons cited by the consumers for not preferring the white ants among other traditional food sources included: high cost of obtaining some of these foods though white ants are not expensive, many people believed that the ants are seasonal and therefore their costs may be relatively higher. Others wanted to abandon old and traditional cultures by embracing the modern food types. Yet others still believed that it is time consuming to prepare the white ants meals, though this seems to be an answer out of ignorance.

Table 4.5: Reasons why the consumers do not prefer white ants

	Frequency	Percent
Abandonment of culture and tradition	67	27.9
Expensive	28	11.7
Time consuming during preparation	86	35.8
Seasonality	58	24.2
Total	240	100

CHAPTER FIVE

DISCUSSION

5.1 Proximate composition of white ants used as food in Western Kenya

Fish and beef are the popular market value foods for the local community members in rural and urban areas, and belong economically to the different traditional grades, according to consumer preference in Kenya. However, in many parts of Western Kenya, especially during the rainy seasons, there has been an unrecognized role of white ants, which swarm in high density and has traditionally been used as food for decades in the areas. Therefore, analyzing the proximate content of the white ants relative to the traditional protein contents is important component of increasing the traditional food items to the local community members. Proteins, lipids, ash, crude fibre, NFE and moisture contents as well as the caloric values were the major constituents, which had been considered in evaluating the nutritional value of the food items studied. Analysis of the ingredient composition and the profile of the essential amino acids (EAA in g/100 g feed) of the white ants when compared with two other protein diets commonly consumed by the local community members indicated that protein content of the white ants was 54% compared to 66% and 62% respectively of fish and beef. The high protein content in the white ants compares well with that of the meat and poultry product (Cherop *et al*., 2009). This is in-line with the report of Steffens (2006), that protein forms the largest quantity of dry matter in many insects, fish and beef. The variations recorded in the concentration of the different proteins in the white ants, fish and beef examined could have been as a result of the rate in which these components are available in the environment as food items (Yeannes and Almandos, 2003), and the ability of these organisms to absorb and convert the essential nutrients from their diet or the environment where they live. This is supported by the findings of Window et al. (1987), Adewoye and Omotosho (1997), Prapasri et al. (1999), Ricardo et al. (2002), Adewoye et al. (2003) and Fawole et al. (2007). Although the protein content of the white ants was lower than that of beef and fish, it provided the required optimal protein content required for the humans (WHO, 2005). This makes the whiteant important living resource of dietary protein as other food like fish and beef.

Fats and oils (hereby referred to as lipids), and thus triglycerides, are present in both animals and plants. Some fat is required within the diet to supply important fatty acids, which are essential regulatory elements. Body fat is needed within our diet as indicators of delivering two essential fatty acids, linoleic acid, an ω-6 PUFA, and α-linolenic acid, an ω-3 PUFA (http://EzineArticles.com/4727184). In this study, the lipid content of the white ants was about 10% and due to the consumption by the local community members, the total intake of lipids in diet was found to be 14 g/100g which was lower than 25 g/100g per day recommended by the WHO (2002). The other food items had lower than 7% crude lipid, which makes their contribution to the overall fatty acids to be somewhat lower.

The dietary requirements of other food items such as ash and crude fiber are not known in humans because these are not essential to the diet but fibres are important in digestion of the food items. Therefore the values presented in this study of the content of ash and crude fibre are only useful in the context of their secondary roles in the human body and in this context the high fiber in white ants are important to enhance digestion of the food in the body.

In this study the whiteants supplied 4.2 kcal energy per 100 g feeds and up to 14.3 g per 100 g energy after consumption. Adequate carbohydrate stores are critical for optimum body energy requirements. While the amount of carbohydrate required to avoid ketosis is very small (about 50 g/day), carbohydrate provides the majority of energy in the diets of most people (Stephen *et al*., 2005). There are many reasons why this is desirable. In addition to providing easily available energy for oxidative metabolism, carbohydrate-containing foods are vehicles for important micronutrients and phytochemicals. Dietary carbohydrate is important to maintain glycemic homeostasis and for gastrointestinal integrity and function. Unlike fat and protein, high levels of dietary carbohydrate, provided it is obtained from a variety of sources, is not associated with adverse health effects. Diets high in carbohydrate as compared to those high in fat, reduce the likelihood of developing obesity and its co-morbid conditions. An optimum diet should consist of at least 55% of total energy coming from carbohydrate obtained from a variety of food sources. When carbohydrate consumption levels are at or above 75% of total energy there could be significant adverse effects on nutritional status by the exclusion of adequate quantities of protein, fat and other essential nutrients. In arriving at its recommendation of a minimum of 55% of total energy from carbohydrate, the consultation realized that a significant percentage of total energy needs to be provided by protein and fat, but that their contribution to total energy intakes will vary from one country to another on the basis of food consumption patterns and food availability. Consuming adequate carbohydrate on a daily basis is necessary to meet the energy (calorie) requirements of the humans to replenish muscle and liver glycogen. Costill et al. (2010) found a direct and positive relationship between the quantity of carbohydrate consumed (188 to 648 g carbohydrate/day) and the amount of muscle glycogen synthesized during 24 hours of recovery from glycogen-depleting exercise. A diet providing 525 to 648 g of carbohydrate (7 to 10 gm of carbohydrate/kg) promoted glycogen synthesis of 70 to

80 mmol/kg and provided near maximal repletion of muscle glycogen within 24 hours. The Institute of Medicine recommends 130 grams (520 kilocalories) of carbohydrate per day. In comparison to the current feeds, white ants, fish and beef had low carbohydrates content resulting in low gross energy than the overall requirements for the humans (WHO, 2002). However, comparatively, the whiteants had the highest content of gross energy partly attributed to the highest consumption of the whiteants during the sampling period rather than due to levels of nitrogen free extracts (NFE) in the food item.

The profile of the amino acid of the feeds were also analyzed and based on the essential amino acid scores, essential amino acids (EAA) of the white ant was the lowest (24.5 g/100g) while that of fish was the highest. However, the profile of the EAA score as a percentage of the crude proteins in the feeds was similar for all the feeds at 46%, which implies an excellent amino acid profile in the diet. The high lipid content in the diet (through observation) compares well with high lipid food items like fish oils (Nowak, 2006). Such lipids will result to the protein sparing effects when being used and therefore it is possible to obtain higher energy from the food and sparing the high protein in the diet for growth. The present work has elucidated more on the importance of white ants as good sources of protein and lipids and has also broadened our knowledge on the nutritional value of some

5.2 Changes in nutrient composition of the white ants following traditional and modern preservation methods

Food is a highly perishable commodity and if not properly handled, quality deteriorates which can have detrimental consequence for the health of the consumers. Various preservation methods have been used worldwide. In Africa, mostly in the sub-Saharan countries, drying, smoking, frying and chilling, enhances preservation. In this study, the white ants were preserved and changes in the proximate composition analyzed. Food diets which are not balanced cause up to 30% of the food borne illnesses in the world (Piel, 2003).

Lack of advanced methods of technology in preservation like canning and deep freezing is openly evident in Kenya (Odero, 2000) though they have been greatly effective as used in Japan, U.S.A., Netherlands and other developed countries. Although technologies for the control of spoilage of animal food and other food products have been well established, tropical countries have been unable to apply them due to the cost, the sophistication of such technology or social cultural factors (Ledward, 1993).

Kenya being a developing country has not put into place these advanced preservation methods like freezing and caning. This has left the use of traditional methods like sun drying, smoking, and frying into great use. Food preserved using these methods has been degraded in quality as stated by the food vendors hence they have been seen to be probably not completely effective. According to Gerasimov (1979), fresh food transported in ice was seen to deteriorate due to temperature, type of transport and duration of transport making the ice to thaw. More so poor quality of ice that is contaminated by coil forms has been a cause of contamination. Sun drying food on the bare ground, mats and nets expose the food to contamination by sand and dirt.

Freezing was the only preservation method that increased moisture content in the white ants. Roasting and sundrying resulted to most significant increase in moisture loss in the white ants. On the other hand, freezing did not produce significant reduction in the protein content while roasting and sundrying resulted to most apparent loss of crude protein content in the white ants. Highest ash content was obtained in frozen product while lowest ash content occurred in sundried and roasted ants. Crude fibre content in the diet were enhanced by freezing while sundrying and roasting resulted to significant reduction in the crude fibre content in the white ant. Finally gross energy did not significantly change in all the preservation methods.

Post harvest losses on small-scale can be among the highest for all commodities in the entire food production system. When the processing, distribution and marketing system cannot cope with the large quantities of foods that are sometimes realised due to seasonal and inter-annual variations of availability or abundance. Appropriate preservation methods can significantly reduce this loss.

5.3 Consumer preferences of the white ants against conventional food sources.

Many Kenyan communities have been observed to use traditional food sources that are highly nutritious without having any scientific attachment to the observed phenomenon. In many parts of the Kenya, white ants are being consumed in many forms. It is the preference of using the white ants that differ in many parts of the country. In Kamukuywa, many people use white ants as a delicacy. The consumers ranked white ants as the third most preferred food item than beef and fish. Though no studies is currently available on the food value of the ants, many Kenyan cherish beef and fish and therefore if white ants ranked third after these food then it is probable to suggest that white ants are actually a preferred foods item. Probably because it is less available, many people do not understand how to obtain it and this could explain why it is not ranked above fish and beef that are frequently available. One of the possible reasons for the reduction in the consumption of white ants could be related to reduction of quantity of the white ants, encroachment of many vegetated zones that were once habitats of white ants as well as changes in the production and consumption patterns of many communities in Kenya.

Preferences of traditional food items in Kenya have been documented to be variable and a function of many interrelated factors. The main reasons however, why the white ants were more preferred was because of their cultural attachments (54.2%) followed by their nutritional contents (35.2%) while others believed that it is less costly than other food items. As already pointed out, no research has been conducted in Kenya to determine the preference of white ants but other reasons for preferring traditional foods are available. Abdala *et al*. 2007 reported preference of local traditional foods in many parts of inland and hinterland parts of Kenya in Murang'a. Furthermore, Wanjiku (2004) also documented after series of field surveys that Kenyans of certain age brackets mainly the old, prefer traditional food items than the young ones. Awiti (1991) documented that between 1960-1980, over 40 varieties of traditional food sources were being consumed across the country. The present study however cannot confirm or deny any reduction in diversity of the traditional food sources in relation to earlier studies because it was only limited to Western Kenya. In his earlier work Awiti considered all traditional food items in Kenya, which was out of current study scope. However, considering the preferences for the few species of established foods such as beef and using evidence from many published literature of the great diversity of traditional food items, in many parts of Western kenya, all evidence suggest non-preference for a number of traditional food items even though white ants were preferred. This seem to suggest that even though many people are consuming the white ants as a cultural obligation, a vast majority of the consumers who seem to be drifting away from the cultural obligation are the major culprit in the consumption of the indigenous white ants

Consumers did not prefer the white ants among other traditional food sources due to a combination of factors including: high cost of obtaining some of these foods though white ants are not expensive, many people believed that they are seasonal and therefore, its costs may be relatively higher. Others wanted to abandon old and traditional cultures by embracing the modern food types. Yet others still believed that it is time consuming to prepare the white ants meals, though this seems to be an answer out of ignorance. The demand driven supply of product is a principle law governing production and marketing of many products outside convectional agriculture or horticulture (Todaro, 2002). This guarantees by the fact that the people will be willing to purchase what is supplied in the market and sellers will be willing to supply what the people are willing to purchase. Though supply and demand laws seems to be the driving force behind the production and the consumption, other intrinsic factors like flavour, nutrition status and acceptability are also important factors that are worth considering. This therefore implies that sustainability in the production of white ants will be achieved if many people determine the critical role played by these white ants in the diet. It is now more recognized that sustaining the production of white ants will not focus on increasing land area for production but intensification of production per unit area since this is done in situ.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

White ants are a valuable source of nutrition in rural areas and contribute substantially to protein and lipids intake. This was evident from the availability of high quality protein content and other ingredients that would render it suitable food to be used overally by the communities.

Freezing was the only preservation method that increased moisture content in the white ants, roasting and sundrying resulted to increase in moisture loss; roasting and sundrying resulted to loss of crude protein, freezing accounted for most loss in ash and crude fibre. Gross energy did not significantly change in all the preservation methods.

Consumers' preference of the white ants ranked after poultry and beef mainly because of cultural attachments and nutritive values of the white ants. White ants were not consumed mainly because of the availability.

6.2 Recommendations

1. White ants should be considered a delicacy and be advocated for all Kenyans to take as long as they are available to reduce over-reliance on poultry and beef.

2. The chemical composition could influence the post-harvest processing and storage and could assist in determining the suitability of the different species to specific processing and storage techniques.

3. Ways of enhancing commercial production of the white ants should be improved to ensure that the ants are available as a major food source.

4. Campaign of making the white ants a delicacy should be started by all the relevant stakeholders.

5. Further determination of quantity of carbohydrates and lipids should be undertaken in the various species of white ants at an advanced stage to enhance its wide acceptability using nutritional information.

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APPENDIX:

1. QUESTIONAIRE.

NATIONAL MUSEUMS OF KENYA

(IN COLLABORATION WITH KARI, UoN, MINISTRY OF LIVESTOCK DEVELOPMENT AND KEBS)

RESEARCH TITLE: INSECTS AS FOOD SOURCES FOR IMPROVING FOOD SECURITY, RURAL LIVELIHOODS AND ADAPTATION TO CLIMATE CHANGE.

Survey questions:

QUESTIONNAIRE IDENTIFICATION

Serial number of the questionnaire: ……………………………….

Date of interview ……………… Start time………….. End Time………………

Name of the interviewer ………………………………………………………….

Name of the respondent:…………………………… 1=Male 2=Female

District: ……………………………………………

Division …………………………………………...

Sub-location……………………………………….

Village …………………………………………….

HOUSEHOLD CHARACTERISTICS

Household Roster: Members of Households, Education, and Employment

Name of the head of household: ………………………. Age ………….. (years)

Gender of the head of household: 1=Male 2=Female

2.3 How long has the household been involved in farming? .... (*Number of years*)

2. 4 Household size ……………………………………

2.5 How many wives does the HH have: _________ *(note to enumerators: please include entire family, including from all wives, below*, ask if not man, is the woman widowed, single)

Household Roster- Please fill in the all the household members

No.	2.6 Name (ok if first name only)	2.7 Relation to household head ***(Key)***	2.8 Gender 1= Male 2=Female	2.9 Age (years)	2.10 Marital status (Key)	2.11 Highest education level achieved **(Key)**
1						
2						
3						
4						
5						
6						
7						
8						
9						

Codes for 2.7 – Relation to household head

1: Head

2: Spouse 1

3. Spouse 2

Code: 2.10 Marital status

1=Married

2= Single

3= Divorced

Code: 2.11 Level of education

1=None 4= Tertiary

2= Primary

3= Secondary 5= Others (Specify)

Occupation of the Respondent

2.12 What is the main occupation of the respondent?

1. Farming

2 Agricultural casual labour

3 Non agricultural casual labour

4. Self employment (business)

5. Formal employment

6 Other (specify) ……………………………….

2.13 Is the household head involved in any other occupation? 1= Yes 2= No

2.14 If yes, what is that occupation?

………………………………………………………………………………………

3.0 CROPS GROWN BY THE HOUSEHOLD. LIST THEM ACCORDING TO PRIORITY

No.	Crop	Acreage (Acres)	Purpose: 1 = Commercial 2 = Household use 3 = Livestock feed 4= Other (specify)
1			
2			
3			
4			
5			

4.0 TYPE OF LIVESTOCK KEPT BY THE HOUSEHOLD (prioritize)

No	Type of livestock	Purpose: 1= Commercial 2 = Household use 3 = Other (specify)
1		
2		
3		
4		
5		

5.0 INFORMATION ON INSECTS

5.1 Are you aware of any edible insects?

1=Yes 2=No

5.1.1 If yes, list (with their local names)?

Name of insect	Local name

5.2 Do you consume any of the above insects?

1=Yes 2=No

5.2.1. If yes, list?

………………………………..……………………………………………………………

……………………………………………………………………………………………

……………………………………………………..………………………………

5.2.2 If No, why?

……………………………………………………………………………………………

…………………………………………………………………………………………

5.3 Do you collect these edible insect?

1=Yes 2=No

5.3.1. If No, list the source(s) of where you obtain these edible insects?

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………

5.3.2. Which of the below listed factors are involved in the collection of insects?

1=Equipment

2=Labour

3=Others (specify)

……………………………………………………………………………………………

……………………………………………………………………………………………

5.3.3. Of the listed factors (5.3.2) what are the quantities and costs of each?

Factor	Quantity	Cost/price

5.3.4. Who collects the insects?

1=Head of the household

2=Spouse

3=Child male

4=Child female

5=Hired labour male

6=Hired Labour female

7=Others (Specify)……………………………………

5.4 In what state do you purchase the insects?

1=Alive

2=Dead

5.5 If you buy, at what price?

Name of insect	Unit(Kgs.)	Price per Kilo

5.5.1 If you sell, who benefits from the sale of insect?

1=Head of the household

2=Spouse

3=Others (specify)………………………

5.6 Which of the listed reasons make you consume insects?

1=Preference

2=Attitude

3=Availability and accessibility

4=Culture

5=Lack/scarcity of other sources of foods

6=Nutritional value

7=Others (specify) -------------------------------

5.7 What is the mode of consumption?

Name of insect	Mode of consumption (**Code**) Code: Mode of consumption 1=Raw, 2=Frying, 3=Roasting, 4=Boiling, 5=Others (specify)……………………..

5.8 How often do you consume these insects in your household?

Consumption pattern	Type of meal: 1= main meal 2= snack 3= vegetable	Name of insect
Daily		
Weekly		
Monthly		
Other (specify)		

5.9 Is the harvesting of edible insects seasonal?

1=Yes 2=No

5.9.1 If Yes, when are the seasons and what insects are available?

Season		Type of insects	Quantity (Kgs)
LR	SR		

5.9.2 If No, list?

……………………………………………………………………………………………

…………………………………………………………………………………………

5.10 Do you store the edible insects?

1=Yes 2=No

5.10.1. If yes, how do you store?

1=Freezers

2=Drying

3=Cooking

4=Smoking

5=Using other substrate (which ones)……………………………….

6=others (specify)……………………………………………………

Name of insects	Type of constraint	What do you do (local Intervention)	What could be the solution if the local does not work (possible intervention)

5.10.2. What constraints do you face while storing insects, what solutions do you have in place and what are the possible intervention mechanism?

5.11 Are there any preservation methods applied?

1=Yes 2=No

5.11.1 If yes, list

………………………………………………………………………………………

………………………………………………………………………………………6. 0

CLIMATE CHANGE

6.1 Have you observed any change in the weather patterns?

1=Yes 2=No

6.2 If yes, tick the changes:

1= Little rain 2= Too much rains 3= Unpredictable rainfall patterns

4= New diseases

5= Others (specify)…………………………………………………………..

6.3 What did you do as a coping strategy?

Climate Change	Coping Strategy (**Use Key)**	If 9 or 10 (examples)*
Little rain		
Too much rains		
Unpredictable rainfall patterns		
New diseases		
Others (specify)**		

KEY

1= Did nothing 2= sold livestock 3= Borrowed from relatives 4= ……

5= Ate other foods especially insects 6= Ate less 7= sought off-farm employment

8= migrated to other places

9= Planted drought resistant crops (Give examples……………………………………)

10= Planted other crops (Give examples)

11= others ………………………………………………….

6.4 In your opinion, what has been the effect of climate change on edible insects?

Climate change (see 6.3)	Effect on insect 1=Increased, 2=Remained the same, 3=Reduced, 4=Others(specify)