Czech University of Life Sciences Prague

Faculty of Tropical AgriSciences

Alternative Sources of Animal Protein in Tropical and Subtropical Regions of Africa

Bc. Thesis

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

BACHELOR THESIS ASSIGNMENT

Rebeka Hadlová

Agriculture in Tropics and Subtropics

Thesis title

Alternative Sources of Animal Protein in Tropical and Subtropical Regions of Africa.

Objectives of thesis

Objective of this thesis is the investigation of available literature sources and electronic information sources to analyze the alternative sources of animal proteins, map out their amount and variety and analyze the processing methods.

Methodology

The work is based mainly on online research of alternative animal protein sources in Africa. A systematic literature review is performed using an electronic search of ScienceDirect, Scopus, Web of Knowledge and Google Scholar. Primary search terms used are: “proteins”, “insect”, “human nutrition”, “food processing”.

The proposed extent of the thesis

30

Keywords

proteins, insect, human nutrition, animal protein sources, Africa, food processing

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Recommended information sources

Tabassum, A., Abbasi, T., Abbasi, S.A., 2016. Reducing the global environmental impact of livestock production: the minilivestock option. Journal of Cleaner Production 112, 1754-1766.
Web of Science
Xia, Z., Wu, S., Pan, S., Kim, J.M., 2012. Nutritional evaluation of protein from Clanis bilineata (Lepidoptera), an edible insect. Journal of the Science of Food and Agriculture 92, 1479-1482
Zhao, X., Vazquez-Gutierrez, J.L., Johansson, D.P., Landberg, R., Langton, M., 2016. Yellow Mealworm Protein for Food Purposes – Extraction and Functional Properties. Plos One 11.

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Declaration

I declare that I have worked on my bachelor thesis "Alternative Sources of Animal Protein in Tropical and Subtropical Regions of Africa" on my own using only cited literary sources, other information and sources.

In Prague 21.4.2017 _____

Rebeka Hadlová

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I would like to thank my supervisor Ing. Iva Kučerová, Ph.D. for her professional consultations and help. And I would also like to thank my sister for her help during my studies in general.

Abstrakt

Studie se věnovala problémům způsobeným nedostatkem živin v Africe a hledáním alternativních zdrojů bílkovin pocházejících ze živočišné říše. Záměrem práce bylo pomocí výzkumu odborných studií, získaných z elektronických a literárních databázích a zdrojů, shrnout možnosti využití hmyzu jako zdroj bílkovin v Subtropické Africe. Začátek práce se věnoval problémům v Africe jako je nedostatek potravin, vysoká úmrtnost, chudoba a politická situace. Dále se práce soustředila na entomofagii, specifické jedlé druhy hmyzu pro danou oblast, obecnou definici, možné alternativy, které by mohly sloužit jako řešení nedostatku živin v potravě v budoucnosti a popis hlavních identifikovaných jedlých druhů hmyzu.

Třetí část studovala dané zástupce. V této části byl každý z nich zařazen do svého řádu a dále charakterizován. Byly vyjádřeny nutriční hodnoty a současně popsány nejznámější způsoby přípravy. Pět ze zástupců bylo detailně popsáno. Mezi tyto jedince patřili *Gonimbrasia belina, Cirina forda, Macrotermes bellicosus, Encosternum delegorguei* a *Acanthacris ruficornis.*

V dnešní době je entomofagie považována za řešení hladomoru ve většině rozvojových zemích. Chov hmyzu je prokazatelně méně finančně náročný než chov dobytka, produkce ozonových plynů je značně nižší v porovnání s dobytkem. Hmyz pro své pěstování nepotřebuje celá pole, efektivita produkce je nepopiratelně vyšší a nutriční hodnoty jsou srovnatelné.

Klíčová slova: hmyz, dostatek potravin, výživa, jídlo, bílkoviny, lidská výživa, bílkoviny zvířecího původu, Afrika, zpracování potravin

Abstract

The study addressed problems caused by lack of nutrients in Africa and searching for alternative sources of protein from the animal kingdom. The aim was to investigate the available information sources including literature and electronic informational databases get a general overview of the possibilities of using insect as a source of protein in Subtropical Africa. The beginning dealed with complications in Africa regarding hunger, mortality, poverty and political situation. Then it focused on entomophagy, specific animal kingdoms, general definition, possible alternatives to provide solution to famine in the future and description of the major identified edible insects. The third part was focused on specific representatives. In this section, each of them was categorized into their order, they were characterized, their nutritional values were described and the most well-known way how to prepare them was identified. Five specimen were chosen and described into greater detail, namely: *Gonimbrasia belina, Cirina forda, Macrotermes bellicosus, Encosternum delegorguei* a *Acanthacris ruficornis*

The entomophagy is nowadays considered a solution to famine in many developing countries. Farming insects is proven to be less expensive than farming livestock, the production of ozone gases is significantly reduced in comparison to livestock. Insects do not occupy entire fields; the efficacy of production is undeniably higher and nutrition values are comparable.

Keywords: insect, food security, nutrition, food, proteins, human nutrition, animal protein sources, Africa, food processing

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1. Introduction

Insects are a big and crucial part of food chain. Not only for people but also for other predators such as reptiles, fish and other mammals. The diversity of accessible kinds of insect is so vast that it represents a wide range of alternative proteins sources. English economist Thomas Maltus stated already two hundred years ago that amount of people living on Earth will increase quicker than food sources and therefore it is inevitable to use insects as adequate source of proteins (Halloran, 2013).

It is essential to choose the right kind of insect with short generation period, great amount of nutrients and easy to breed. One of the most popular components are proteins, vitamins and amino acids, which are vital for human body and its smooth working. Moreover, the expenses for breeding insects are incomparable with cattle farming. For example crickets need six times less food than cows, four time less than sheep and two times less than broiler chickens or pigs (Halloran, Roos, Eilenberg, Cerutti, & Bruun, 2016). Also, their life cycle and farming, produce significantly less greenhouse gases than conventional livestock (FAO, 2010).

All sorts of orthophterous kinds, beetles, dipterous kinds, crickets and above all cockroaches, which have been extremely popular, have been used traditionally for breeding. They are no longer taken as pest and unwelcome insects. In present, we know over three thousand edible insects and it is more than likely that the number will increase. Usually in the past scientists were studying and growing cosmopolitan kinds but nowadays the exotic types are more and more widespread. Mostly because these kinds of insects need higher temperatures than what is common in continental Europe so there is not the risk of escape and overpopulation (Kelemu et al., 2015).

It is very hard to tell the precise amount of nutritional potential of insects globally because they are such a big and diverse group of animals. Each kind contains different combination of substances. For consumption and preparation, it is crucial to know how to do it while preserving the nutritional capacity, without employing preservatives. Worms of *Gonimbrasia belina, Omocestus viridius, Isoptera,* maggots of bees have ranked among the most popular to include in African diet. (Borkovcová, 2015).

2. Objectives

The aim of the work was to investigate the available information sources including literature and electronic informational databases to get a general overview of the possibilities of using insect as a source of protein in Subtropical Africa. Specific objective was to describe species of insect suitable for inclusion in human diet, compare and evaluate them and find various ways of their preparation and their nutritional values

3. Methodology

The methodology was literature based research. The research was founded on online databases such as EDS, FAO, EBSCO Discovery Service and AGRIS with the help of key words (food security, entomophagy, insects, edible insects, nutrition and African cuisine). Information was accumulated through reading, comparison and search for data about entomophagy in Africa.

4. Literature review

4.1 Africa

4.1.1 Basic information

Africa is the second largest and second most populated continent in the world. The inhabitants make up 14 percent of world´s population which means that the total amount of people is approximately 1, 070,000,000 (Reader & Rogers D. Spotswood Collection., 1998). The continent is surrounded by Mediterranean Sea in the north, Red Sea and Suez Canal in the northeast, the Indian Ocean in the southeast and the Atlantic Ocean in the west (Curtin, 1995).

The continent is divided into two main regions- South Africa and Sub-Saharan Africa which includes most of the area- 80.3%. This division was made based on cultural and political features. There are 55 internationally recognized countries on the continent. Because of its enormity Sub-Saharan Africa is further divided into four distinct parts: Western Africa (Benin, Burkina Faso, The Gambia, Ghana, Guinea, Guinea-Bissau, Cape Verde, Liberia, Mali, Mauritania, Niger, Nigeria, Côte d'Ivoire, Senegal, Sierra Leone and Togo), Central Africa (Chad, Republic of the Congo, Gabon, Cameroon, Congo, Central African Republic, Sao Tome and Principe Island), Eastern Africa (Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Seychelles, Somalia, Sudan, South Sudan, Tanzania and Uganda) South Africa (Angola, Botswana, South Africa, Comoros, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Swaziland, Zambia and Zimbabwe) (Bohannan & Curtin, 1988).

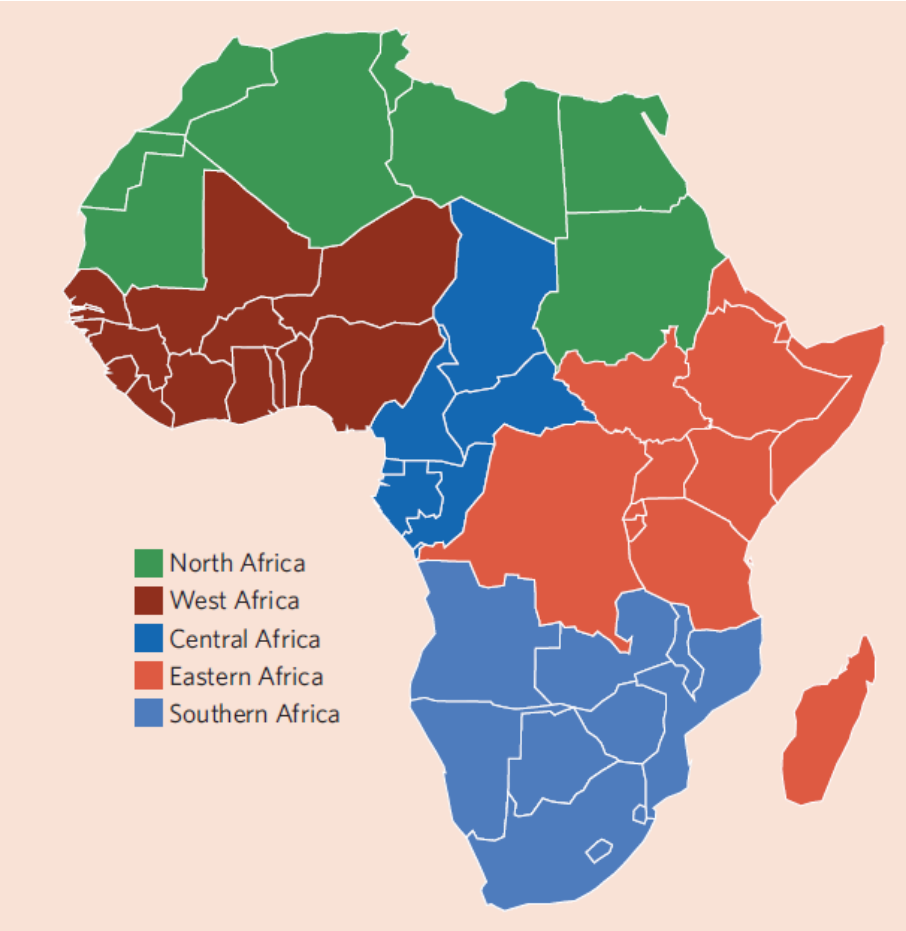

Figure 1. African subregions *(United Nations, 2015a)*

The exponential population growth is alarming. The population is largely young. According to UN report, 43% of inhabitants are younger than 15 years and only 3% are older than 65 years. Nonetheless it needs to be stressed that the people living up to 65 years of age come mainly from the surrounding islands. Life expectancy in Sub-Saharan Africa is 57. This number is so much lower mostly because of civil wars and various diseases along with lack of accessible health care. One of the crucial problems of African population, mostly Sub-Saharan, which significantly shortens the overall life expectancy is the HIV virus and subsequent AIDS. This disease is especially detrimental to the age groups in range from 15 to 49 years old (United Nations, 2015b).

The number of HIV positive people has increased by 81.5% in last twenty years. Countries with highest numbers of newly infected people are Swaziland 34.2%, Botswana 26.8% and Lesotho with 26.6%. (Population Reference Bureau, 2016). For comparison, in Europe the

number of HIV positive patients has doubled in the same period. The problem is that the statistics do not calculate with people who do not know that they are HIV positive or people who do not undergo the tests and subsequent treatment.

One of most important figures, which summarizes the alarming situation in developing countries, is the children mortality rate, here the number of children who do not live up to 5 years of age. The counts decrease worldwide but there is a significant difference in the speed of the decline. In the past 60 years the situation has improved 3.2 times but it is still falling behind compared to South Asia which has improved 6.1 times or Southeast Asia with 9.1 times or Europe with 15.6 times. In worldwide range the number is 4.6 times better nowadays than it used to be. In Europe the mortality is almost eliminated (United Nations, 2015b).

The reason for the great differences as presented above is poverty. Sub-Saharan area is among the poorest regions in the world. Despite the obvious effort, numbers of surviving children increase but only slowly. It is shocking since the area has great wealth in the form of natural sources. Despite the natural sources, almost 50% of inhabitants live on less than 1.25$ per day. (Nation, 2014).

How is it possible that countries with such potential are so poor? The answer is because of Europeans and Asian Neo-Colonists. One of the major reasons for development of struggling economies across African continent is extremely high rate of corruption. According to one Swedish report conducted by international development agency, Forum Syd, tax dodging of multi-national corporations running their businesses from Africa is more harmful to the local economies than corrupt leaders. The study shows that the amount of money, which Africa would earn, if the businesses were fair, from the taxes would be a staggering 160bn $ which are instead either transferred into Western banks and boost Western economies or they are sent to be protected in the so called tax heaven (Moore, 2014).

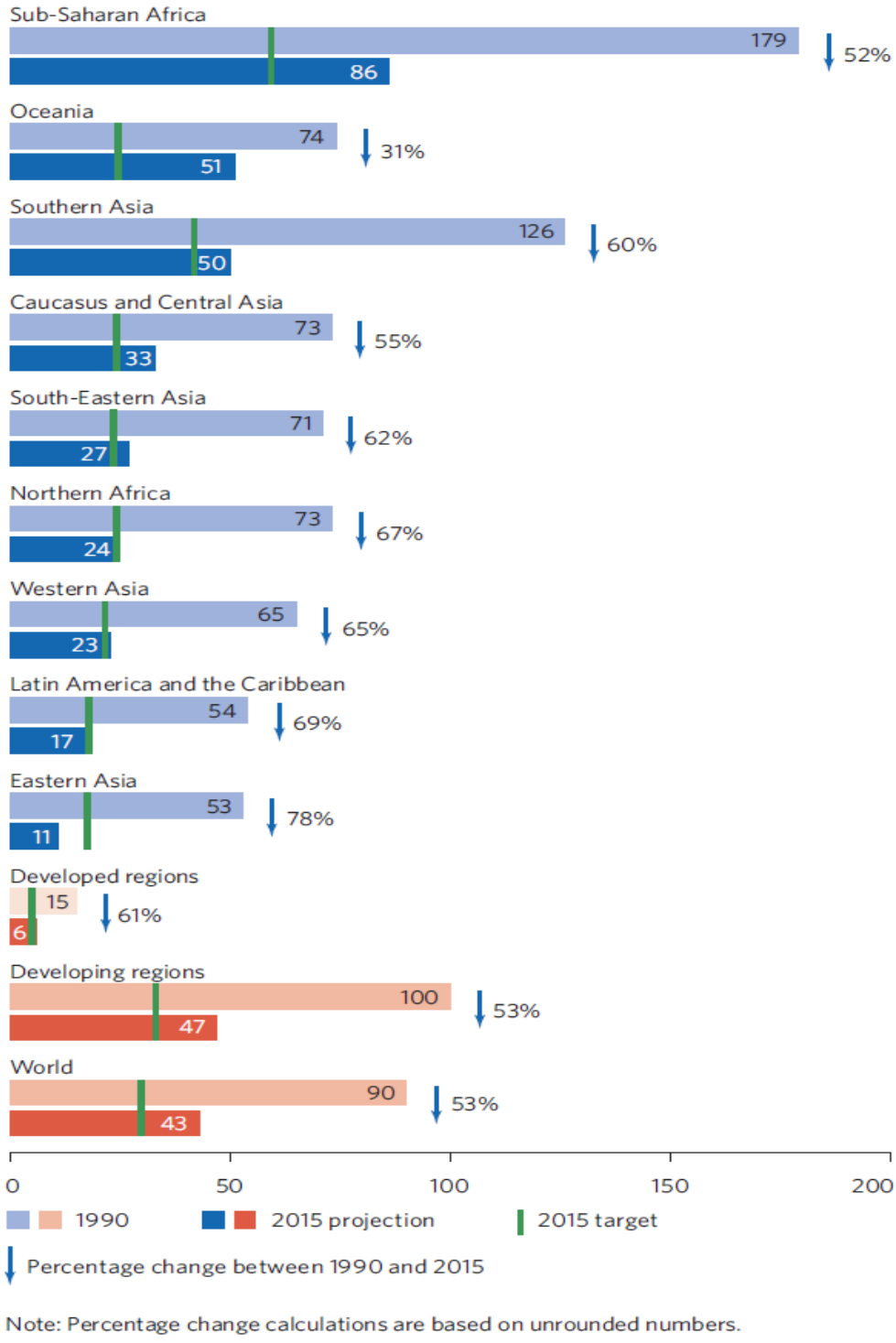

Figure 2. Under-five mortality rate, 1990 and 2015 (deaths per 1,000 live births) *(United Nations, 2015a)*

Another important source of potential income are the surrounding waters of African continent. They are supposedly one of the richest fishing grounds in the world. But thanks to industrial fishing boats the naturally occurring fish populations are rapidly brought onto the verge of extinction. The industrial boats catch more fish in one day than 50 traditional barges during an entire year. This means that Africa is losing over 1.3$ billion worth of fish to illegal fishing boats from Europe, Taiwan, Russia, China and the Philippines (Moore, 2014).

Unfortunately, this is not an uncommon practice overall in Africa. The majority of profits from mining, healing plants, fish, coffee, cocoa, citrus, cotton goes to big international corporations. And usually they sell the products made from African resources back to African countries (Moore, 2014).

4.1.2 Food in Africa

With poverty usually comes hunger and malnutrition which has become global problem of developing countries. In the current situation with rapid population growth, food production does not keep up. Food security is set when all people at all time have access to appropriate, nutritious food fulfilling their dietary needs and preferences for active and healthy life (Food and Agriculture Organization of the United Nations, 2006).

In general, local cuisines in Africa are very diverse due to an enormous variety in culture and traditions. Individual dishes are commonly influenced by the typical ingredients, easily accessible in respective parts of the continent. We cannot forget the foreigners who further broadened the African pellet by bringing their traditional cooking to Africa, which has been adopted as local (Newman & Rogers D. Spotswood Collection., 1995).

When we look at East Africa there is undeniable Arab impact. 1,000 years ago Arabs brought wide spectrum of spices along with rice, oranges, lemons and even domestic pigs from China and India. With arrival of British Empire, Indian workers came into the region and they introduced spiced vegetable curries, lentil soup, pickles and chapattis (flatbread). The British themselves influenced locals by bringing their breeds of cattle, sheep, goats and even the exotic coffee (Spooner, 2014).

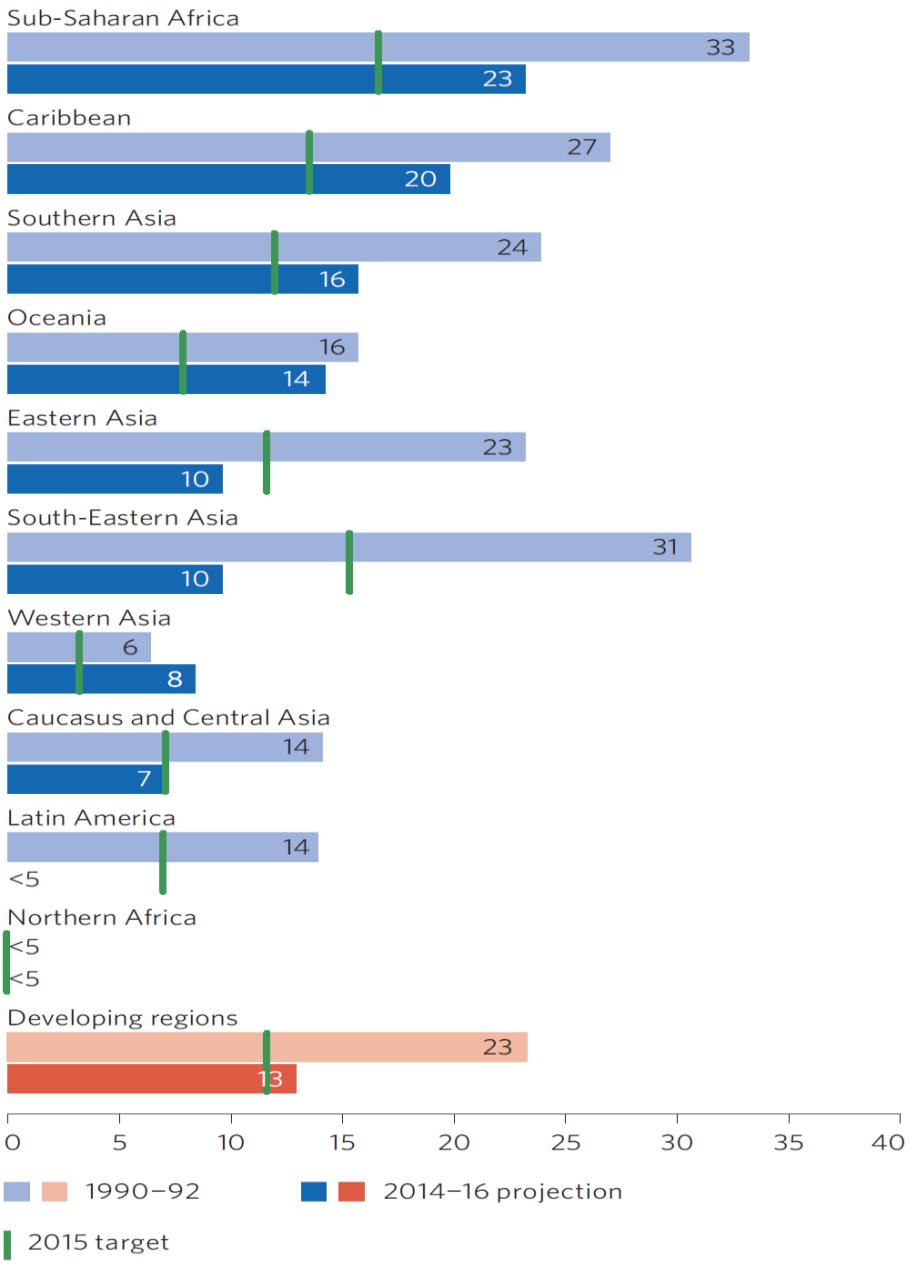

Figure 3. Proportion of undernourished people, 1990-1992 and 2014-2016 (percentage) *(United Nations, 2015a)*

As sheep, goats, cattle were introduced to central Africa they were not accepted as a source of meat. They were considered producers of milk and a form of currency. Therefore, in the eastern regions people use grains, vegetables and fish when they lived near lake or river, as source of proteins. The ground maize is one of the main crops in eastern and southern

Africa. It is used to produce maize flour which is further cooked with water to form dough or tough porridge- called *ugali, nsima* or *sadza,* depending on the region. It serves a traditional source of protein (Spooner, 2014).

When we move to Horn of Africa [1] food eaten in the region is completely different from the cuisine of central and eastern Africa. Islamic and Christian faiths have deeply affected the cuisines. As for Coptic Christians, they implemented fasting days so consumption of lentils and chickpeas increases massively regions with dense Coptic population. For Ethiopian and Eritrean cuisine, it is typical to prepare so called "bytsebhis" which is a stew from meat served with "injera"- a flatbread made of different types of grain (sorghum, teff or wheat). Somalia uses one very unusual ingredient- pasta in its cuisine which was brought by the Italian colonists (Curtin, 1995).

It is said that Southern Africa is the region with the most diverse cuisine of all. It is the result of intense mixing of the cultures. The Portuguese brought the piri-piri, chilli seasoning, other European settlers came up with new techniques of drying thanks to which the well-known dry meat- "biltong" was first prepared. The local communities had already used meat and dairy in their diets before (Hobbs, 2012).

On the other hand, it is not possible to say this about Western and Central Africa because the influence of the Europeans settlers here was not as big as the Arabic one. Africa traded spices with the Arab world. That is the reason their dishes are full of hot spices. With the least of contact with "outside world", Central Africa takes pride in remaining the closest to the traditional tribal cuisine and its ingredients (Spooner, 2014).

4.1.3 Food security

Food security is one the biggest problems with which people must deal on daily basis. Mainly it is the cost of lack of the food but also unacceptability of consumming certain foods plays a crucial role in establishing food security on the continent. Poverty is largely to blame for the insecurity. The rest of the world made a big progress and managed to tackle most causes of poverty but Africa especially Sub-Saharan Africa is falling behind. It

[1] Horn of Africa is an area which includes Djibouti, Eritrea, Ethiopia and Somalia.

has been shown in many studies that the situation would not improve without preventive plan. If no action is taken, the number of people suffering from malnutrition will constantly increase. There are many factors influencing the state of things such as civil wars, diseases, frequent drought and famine, dependency on the climate and environment and of course unstable political situation (Food and Agriculture Organization of the United Nations, 2006).

Almost 80% of the insecure habitants live in the rural areas. Rural areas are responsible for producing around 90% of the continent´s food supply. But 50% of these 80% suffer from malnutrition. Therefore, it is inevitable to change the living situation in these parts. The main change has to be the change of the profitability of the local smallholder farmers (Mwaniki, 2006).

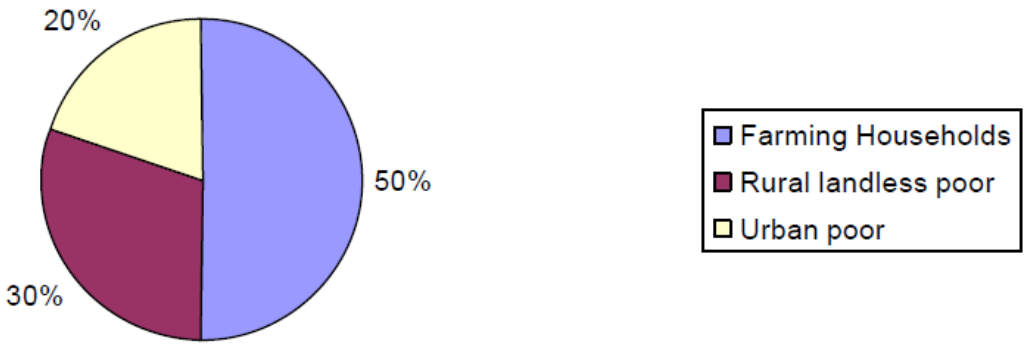

Figure 4. Proportion of the Food Insecure in Africa *(Mwaniki, 2006)*

The market isolation is another obstacle for the smallholder farmers. There are many problems which need to be solved such as lack of information, inadequate supporting institutions and poor policies towards farmers. Farmers are usually used to selling their products at small town farm markets but when they want to make a bigger profit they must move to a bigger market. This change brings problems with stronger competition, claims to quantity, quality and size. These changes do not come easily to traditional farmers (Yates-Doerr, 2015).

4.2. Enthomophagy

4.2.1 Definition of entomophagy

Entomophagy is a technical term for eating insects. Lot of animals are entomophagous for example spiders, other insects, birds, lizards etc. but not just animals also people around the world. In many countries insects are considered a part of a regular diet. But in many western countries this kind of dish is a big taboo. This situation was mainly caused by the fact that farming insects vanished because of colossal agricultural modernizations in livestock farming which have been happening in the past centuries. Of course, some of the insects or rather their products remained a part of the industrial society such as bees or silkworms. Also for very long time insects were not included in any research and developmental planning. Only recently were insects reconsidered as an adequate part of diet for many people. Researches claim that around 2 billion people are active insects eaters (Arnold van Huis et al., 2013).

There are three main arguments to promote entomophagy. The first one is benefits for the health of an individual consumer. Insects are a healthy, balanced option to replace mainstream sources of protein such as beef, chicken, pork or fish. Majority is protein rich, contains good fats, calcium, iron and zinc (A Van Huis, 2003).

Second reason is the decreased demands on the environment. In comparison to livestock insects produce incomparably less greenhouse gases (GHGs). Just two big groups of insects are labelled as significant promoters of GHGs and those are termites and cockroaches. Since they are very small animals, insects do not require big farming lands, land activity or land clearing. Obviously, they do not require big amounts of food either. Organic waste can be used as a source of food for insect to be converted into valuable protein. When we take crickets, it is proven that they need twelve times less feed than cattle, four times less than sheep, and twice less feed than pigs and broiler chickens to produce the same amount of protein (A Van Huis, 2003).

Table 1 Comparison of average protein content among insects, reptiles, fish and mammals (Ramos-Elorduy, 2010)

Animal group	Species and common name	Animal product	Protein content (g/100 g fresh weight)
Insects (raw)	Locusts and Grasshoppers: *Locusta migratoria, Acridium melanorhodon, Ruspolia differens*	Larva	14-18
	Locusts and Grasshoppers: *Locusta migratoria, Acridium melanorhodon, Ruspolia differens*	Adult	13-28
	Sphenarium purpurascens	Adult	35-48
	Silkworm: *Bombyx mori*	Caterpillar	10-17
	Palmworm beetles: *Rhynchophorus palmanum, R. phoenicis, Callipogon barbatus*	Larva	7-36
	Yellow mealworm: *Tenebrio molitor*	Larva	14-25
	Crickets	Adult	8-25
	Termites	Adult	13-28
Cattle		Beef (raw)	19-26
Reptiles (cooked)	Turtles: *Chelodina rugose, Chelonia depressa*	Flesh	25-27
		Intestine	18
		Liver	11
		Heart	17-23
		Liver	12-27
Fish (raw)	Finfish	Tilapia	16-19
		Mackerel	16-28
		Catfish	17-28
	Crustaceans	Lobster	17-19
		Prawn	16-19
		Shrimp	13-27
	Molluscs	Cuttlefish, squid	15-18

The last argument is economic. In terms of economic and social requirements insect harvesting is low on technical equipment, on primer investment so it can serve as a source of food and money also for the poorest landless people. Depending on the primary investment the farmer can decide on sophistication of his farming (Looy, Dunkel, & Wood, 2013).

4.2.2 Benefits of entomophagy

The diversity of arthropod species has developed over the past 400 million years thanks to evolution. Each of the species adopted specifically to their environment. Around 1 million from the total 1.4 million are insects and the number is still not final. It is believed that millions of them exist but are not known yet. Only a fragment of them are labelled as harmful to people, crops or livestock (Lenteren, 2006).

If we look at the benefits considering the nature, insects play a crucial role in plant reproduction. Therefore, they are vital for the survival of humankind. At the moment, around 98 percent of pollinator species which have been identified are insects (Ingram, Nabhan, & Buchmann, 1996). The benefits brought by insects are undeniable.

Another crucial benefit which is usually taken for granted is the involvement of insects in biodegradation of waste. Biodegradation is based on gradual decomposition of organic substances on the ground until they reach a state of degradation which allows fungi and bacteria to consume it. This process allows the minerals and nutrients of the decomposed organism to be absorbed in the soil and ready to be taken by plants (Arnold van Huis et al., 2013).

Insects are beneficial in diverse fields of agriculture. Fly maggots and beetle larvae consume animal tissues and thus help with their biological degradation. Another example are dung beetles which play a significant role in decomposition of muck. A pile of excrement is fully colonized, which means that the colonization block of flies develops on it, in just one day. Additionally, the maggots and larvae help to prevent loss of nitrogen. The losses can be costly when the excrements stay on the top layer of soil and the contained nutrients are not absorbed (Hanboonsong & Durst, 2014).

Maggots and larvae manage to recycle the minerals and carbon back into the soil and further decompose it, converting the material into humus, which is a nutritionally rich

fertilizer for the plants (Arnold van Huis et al., 2013). In fact, all agro systems profit from insect activity because they provide a natural control of the harmful pest species.

The insects are helpful in other surprising ways. There are numerous insect species that parasite on other insects. It is believed that around 10% of all known insects are parasites. This may become useful in cases of invasion of a certain insect species and the resulting destruction of crops. The parasitic insect species may be employed to stop the invasion of the invasive species and prevent massive loss to the farmer as well as the land. Other big group of insects are the predators (e.g. certain kinds of dragonflies, bees, wasp, ants). The predators may be employed by the farmers in a similar way to the parasitic species to protect crops from invasive species. Still a rather large amount of harmful species exists, which may cause damage to people by interfering with farming, destroying crops or parasiting on livestock. These species are partially to blame for the overall negative perception of insects (Cerritos Flores, Ponce-Reyes, & Rojas-García, 2015).

There was a study which showed one specific agroecosystem in rice fields in Indonesia. They recorded 500 beneficial species and 130 pest species. Also another 150 species were marked as neutral because they did not cause any damage to the rice but they play a crucial part in the survival of predators when there was not enough rice (Arnold van Huis et al., 2013).

We also cannot forget the influence and products which insects bring to people. They provide wide range of valuable produce, such as the notoriously known honey and silk. Report shows that bees provide around 1.2 million tonnes of honey per year (Arnold van Huis et al., 2013) and silkworms produce more than 90,000 tonnes of silk per year (Guo et al., 2016).

Another product used in the industries is red dye produced by scale insects which is use as a food, textile and pill dye. Another valuable insect product is the protein resilin used in human medicine for strengthening arteries which has similar qualities to a rubber (Elvin et al., 2005). Another well-established practice in human medicine is maggot therapy, which is applied to taint wounds, blisters caused by burns, festering injury and even diabetic foot or necrotic tissue. In general insects inspire a lot of technologies by their structure and products (Arnold van Huis et al., 2013).

4.2.3 Identified edible insects

To achieve higher inclusion rates of insects in the various diets across the African continent there is an urgent need to portray them in a more positive way. Highlighting their usefulness and the already well-established presence in lives of the western society may greatly help improve their reputation as a valuable source. An ultimate number of those insects which can be consumed worldwide does not exist. This lack of an international list can be ascribed to various reasons. The main one is, a person not educated in Linnaen nomenclature, is unable to categorize insects properly. Also in almost every culture more than just one name for the same insect species is used. By April 2012 Yde Jongema from Wageningen University and Research Centre listed 1,900 edible insects by using only Latin names and rectifying the synonyms. But the numbers are different based on the leading scientist and region. Just for the comparison van Huis (2005) identified 250 edible species just in Africa, in China, Chen et al. (2009) documented 170 species and Paoletti and Dufour (2005) estimated that 428 species were consumed in the Amazon (Ramos-Elorduy, 2010)

Universally there are species which are more popular as part of diet such as beetles (Coleoptera) which represent 31 percent of commonly eaten species. But it is no surprise since the group represents 40 percent of all known insect species. Another famous and big group are caterpillars (Lepidoptera) (represent 18 %) which are mainly consumed in sub-Saharan Africa. The third major group (14 %) contains bees, wasps and ants mostly popular in Latin America. Next come grasshoppers with 13 percent, crickets and locusts, follow with 10 percent cicadas, true bugs, planthoppers, leafhoppers and scale insects are next in their popularity on the list.

Termites and dragonflies both have 3 %, flies 2 % and the rest of species are all make up 5 %. Lepidoptera are consumed in almost every stage of caterpillars' development whereas Hymenoptera are usually consumed as they reach the stage of larva or pupal. Coleoptera are eaten in both stages (as a larva and as an adult), while the Orthoptera, Homoptera, Isoptera and Hemiptera orders are in most cases processed for cooking in mature stage of development (Arnold van Huis et al., 2013).

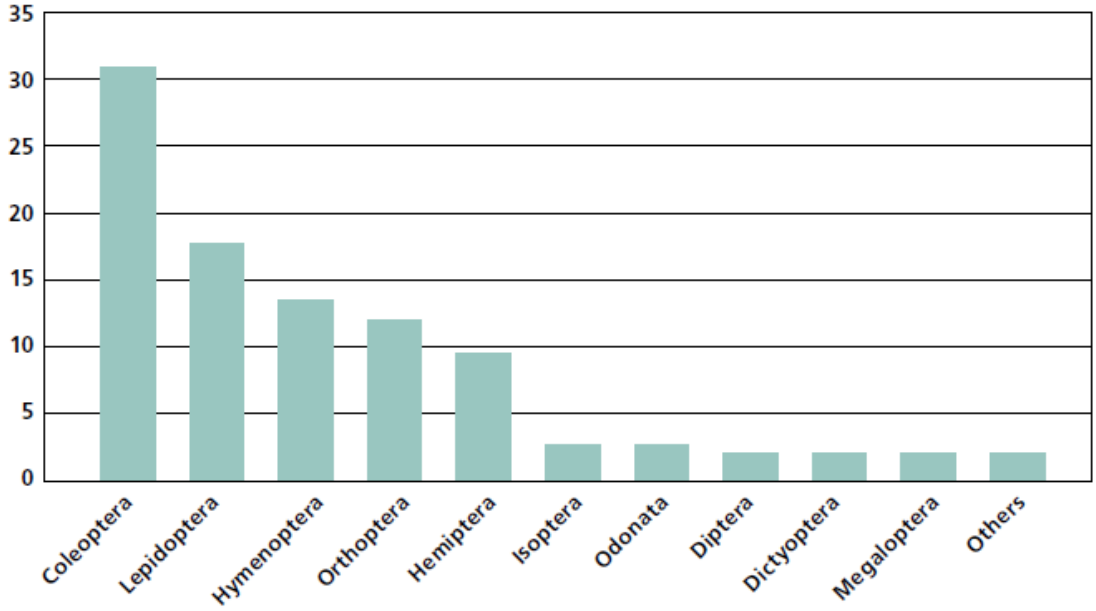

Figure 5. Number of insect species, by order, consumed worldwide (Ramos-Elorduy, 2010)

4.2.3.1. Coleoptera

Beetles represent the biggest group of edible insects. This big group is divided into lot of sub-groups including aquatic beetles, wood-boring larvae and dung beetles. There are believed to be around 78 species of edible aquatic beetles. These species are mostly presented by the Dytiscidae, Gyrinidae and Hydrophilidae families. Only larvae of these species tend to be eaten (Arnold van Huis et al., 2013).

It is known that by far the most popular beetle for cooking in the tropical regions is the palm weevil, *Rynchophorus*, substantial pest of palm trees which can be found all around Africa, southern Asia and South America. The weevil *R. phoenicis* is found in tropical and equatorial regions, *R. ferrugineus* in Asia (Indonesia, Japan, Malaysia, Papua New Guinea, the Philippines and Thailand) and *R. palmarum* in the tropical Americas (Central America and West Indies, Mexico and South America). In Europe, we can come in contact with mealworm species from the Tenebrionidae family, such as the yellow mealworm (*Tenebrio molitor*), the lesser mealworm (*Alphitobius diaperinus*) and the superworm (*Zophobas morio*), which are usually fed to reptiles, fish etc. These representatives of the order have been approved for human consumption as well (Arnold van Huis et al., 2013).

4.2.3.2. Lepidoptera

Butterflies and moths are mostly consumed in their larval stage but it is no exception to eat them as adults. Aboriginal Australians are believed to consume moths of the cutworm *Agrotis infusa* (the Bogong moth) ("Australian Museum," 2012). In other countries it is a common practice to eat hawkmoths (*Daphnis* spp. and *Theretra* spp.) after removing the wings and legs (Ramos-Elorduy, 2010).

One of the well-known representatives which became widely popular in many African countries (Angola, Botswana, Mozambique, Namibia, South Africa, Zambia and Zimbabwe) is the mopane caterpillar (*Imbrasia belina*). Harvesting them is advantageous mainly for economic reasons, in south Africa the practice earns US$85 million (Poole, Frost, Stack, & Madzara, 2004). Other kinds of caterpillars are also exploited. In Democratic Republic of the Congo, Zambia and Zimbabwe around 38 species (Arnold van Huis et al., 2013) were found. Caterpillars can also be found in Asia. There is the bamboo caterpillar whose consumption is supported by the Thai Department of Forestry of the Ministry of Agriculture and Cooperatives because it represents a sure income (FAO, 2010).

4.2.3.3. Hymenoptera

This group can be divided into three main groups- ants, wasps and bees. Ants as almost every animal influence their surroundings both positively and negatively. Mostly they are considered a delicacy in specific parts of world. Their function in nutrient cycling, decomposition and predation of pest insects is indispensable (Del Toro, Ribbons, & Pelini, 2012). In tropics one of the most popular species is the weaver ant (*Oecophylla* spp.). It can be used in multiple ways. In Asia, their larvae and pupae are called ant eggs and they are a popular delicacy. In some parts of China, Sri Lanka, India, Malaysia and Bangladesh species called black weaver ant *(Polymachis dives*) is used to fortify drinks or healthy food as a supplementary ingredient to be later sold on the Chinese market (Arnold van Huis et al., 2013).

Next species are wasps, one very popular species to be consumed in Japan is called hebo. It is a yellow jacket wasp (*Vespula* and *Dolichovespula* spp.), which is consumed in the stage of larvae during the Hebo festival which takes place every year. This one is considered

such a treat that they are commonly imported from Australia and Vietnam to keep up with demand (FAO, 2010).

Bees are well known for their usefulness in nature, agriculture and for their products but their potential as a source of protein is not as widely accepted (Chen, Feng, & Chen, 2009). However, it should be highlighted that a lot of the order families are edible in almost every stage. One study shows that bee brood is superior source of energy, B- vitamins, essential minerals and amino acid (Arnold van Huis et al., 2013). Honeybees (*Apis mellifera*) are considered one of the most important species in the traditional diet consumed in northern Thailand. Thanks to a high demand they are also quite expensive (Chen et al., 2009). In other parts of the world beekeeping can be more profitable than growing crops.

4.2.3.4. Ortopthera

This order can also be divided into three main groups- grasshoppers, locusts and crickets. Grasshoppers are well-known for being the species which is generally edible. Since they are agricultural pests, locusts (mainly the desert locust, the migratory locust, the red locust and the brown locust) are destroyed by insecticides even though they are very easy to harvest thanks to living in swarms (Saeed, Abu Dagga, & Saraf, 1993).

For both species it is typical to be cold-blooded, therefore they are picked-up in the mornings when the temperature is low and the animals are inactive (Cerritos Flores et al., 2015). For example one of those species which need to be collected early in the mornings is grasshopper *(Sphenarium)* because their mobility grows with increasing temperature which means that to collect them, it must be done before they start moving in the morning (Arnold van Huis et al., 2013).

Grasshoppers are often sold on markets or on roadsides as snacks. They are usually more expensive then the millet in which they were caught (Arnold van Huis et al., 2013). The regular process of preparing grasshoppers in Latin America is with a bit of oil, garlic, lemon and salt to improve the taste. They have been part of the diet for centuries.

Crickets such as *Gryllus bimaculatus*, *Teleogryllus occipitalis* and *T. mitratus* and the house cricket *Acheta domesticus* are regularly consumed at the places of their natural occurrence. The house cricket is more popular thanks to its softer shell. Thailand is the country of crickets. Recent study shows that in 53 of 76 provinces people harvest crickets

on their farms (Siriamornpun & Thammapat, 2008). Despite the enormous popularity of harvesting crickets, only two species are edible (*Gryllus bimaculatus* and *Acheta domesticus*). These two are the only ones, which may be harvested for economic reasons. The others are unprofitable due to their long reproduction cycles (Arnold van Huis et al., 2013).

4.2.3.5. Homoptera suborder of Hemiptera

This group contains cicadas, leafhoppers, plant hoppers and scale insects. For eating crickets, it is typical to remove their wings before consumption. Some of the products generated by Homoptera are used in various industrial sectors. For example carmine dye- also known as E120 (present in food products), lerp- matter of sugary secretion which is produced as defensive mechanism by psyllid insects (Arnold van Huis et al., 2013).

4.2.3.6. Heteroptera suborder of Hemiptera

One of those popular species eaten in sub-Saharan Africa, the Republic of Sudan are called Pentatomid bugs. Usually they are consumed roasted but they can also be exploited for oil extraction which are then used for preparation of food and scam disease of camels (Arnold van Huis et al., 2013). Most of these edible bugs are aquatic. The famous goods made from eggs of those species which are part of the Heteroptera family is called “ahuahutle”. It is Mexican version of the famous caviar which contains eggs of at least seven species of aquatic Hemiptera (the *Corixidae* and *Notonectidae* families). The demand for this product rapidly increases the week before Easter. Nevertheless the harvesting is in crisis due to heavy pollution and lack of water resources (Ramos-Elorduy, 2006).

4.2.3.7. Isoptera

The one example of termite which is eaten on a regular basis is *Macrotermes* species. It is typical for them to hatch by the end of the dry season right after the first rain. What the locals do is that they hit the ground close to the termite nest which mimics the feel of the heavy rain and the termites emerge and can be easily caught and subsequently eaten (Arnold van Huis et al., 2013).

4.3 Entomophagy in Africa

The food security situation is very unpredictable, demanding and the source of food is uncertain in some parts of Africa. Insects seem to provide a reasonable alternative as a crucial source of protein and other essential nutrients. As the rainy season periodically returns, fish and hunting mammals becomes problematic. Insects may be the solution to ensuring food security. The availability of certain species varies based on region-specific weather conditions (Vantomme, Göhler, & N'Deckere-Ziangba, 2004).

One study from the Democratic Republic of Congo shows the Ngandu people and their extreme vitality which has been ascribed to their nourishment. They only eat what is available during the given season. The increasing amount of consumed caterpillars in Kinshasa, capital city of the Democratic Republic of Congo, relates to decreasing numbers of fish populations in the surrounding waters (Arnold van Huis et al., 2013). The local people explain eating caterpillars by their agreeable taste and high nutritional values (Vantomme et al., 2004), further proving the point of insects providing a valuable and moreover sustainable food source.

Caterpillars consumption is at its peak during the rainy season, when one person regularly consumes about 42 pieces in one day. In comparison with the dry season when the consumption is much lower (Arnold van Huis et al., 2013) because other sources of nutritious foods are available. Natives pick up caterpillars before the rainy season just before leaves start to grow. It is a common practice to store the surplus harvested insects for future use in the next season in dry form (Arnold van Huis et al., 2013).

4.3.1 Caterpillars

The group of caterpillars is considered one of the most varied group of edible insects. They are a group rich for proteins and micronutrients. In sub-Saharan Africa 30 % of edible insect species are caterpillars (Arnold van Huis et al., 2013). Studies show that 38 species are regularly consumed in the regions inhabited by the Bemba. Bemba are Bantu speaking inhabitants living in the northeast of Zambia and neighbouring parts of the Democratic Republic of Congo and Zimbabwe. In the Democratic Republic of Congo the consumption of caterpillars is so vital that it makes up to 40 % of consumed proteins from animal

sources. On the African continent the most popular species is the mopane caterpillar *Imbrasia* (=*Gonimbrasia*) *belina* (Arnold van Huis et al., 2013).

Table 2. Abundance of caterpillars in Central Africa *(Ramos-Elorduy, 2010)*

Country	Province	Jan	June	July	Aug	Sep	Oct	Nov	Dec
CAR			xxxx	xxxx	xxxx	xxxx			
Cameron				xxxx	xxxx	xxxx	xxxx		
DR Congo	East Kasaï		xxxx	xxxx					
	West Kasaï			xxxx	xxxx	xxxx			
	Bundundu					xxxx	xxxx	xxxx	xxxx
	Kinshasa					xxxx	xxxx	xxxx	xxxx
Rep. du Congo	Sangha			xxxx	xxxx	xxxx			
	Likoula			xxxx	xxxx	xxxx			
	Brazzaville						xxxx	xxxx	xxxx
	Pool	xxxx							
	Plateaux	xxxx							

4.3.1.1 Mopane Caterpillar

The mopane caterpillar flourishes in woodlands, mostly in those found in Botswana, Namibia, Zimbabwe and parts of South Africa (Arnold van Huis et al., 2013). The necessity for further distribution is planting of the host, the mopane tree (*Colophospermum mopane*). The species is bivoltine so it produces (in most of the areas) two generations every year. The first one evolves in the period between November and January and the second comes between March and May (Poole et al., 2004).

They are not just a food source for the times of hunger they have been and they still are a crucial part of the local diet (Vantomme et al., 2004). Women and children hand pick the caterpillars. Usually they are picked in high amounts so the surplus can be gutted, boiled in salty water, sun-dried and stored for use in future months, in times of lack of other food sources. The harvesting of mopane caterpillars is for the most part financially more profitable than income from harvesting crops (Munthali & Mughogho, 1992). The income made by harvesting caterpillars is enough for families to buy basic items for households, cloths and school materials for their children (Halloran, 2013).

It is common for people to travel long distances into the woodlands so they can profit from caterpillar picking (Arnold van Huis et al., 2013).

Nutritional values

Mopane caterpillars are one of the richest sources of essential nutrients. For example, in comparison to hundred grams of dried beef which contains six milligrams of iron, the same number of caterpillars contains up to 31 milligrams. The other vital elements include are significant amounts of potassium, sodium, calcium, phosphorus, magnesium, zinc, manganese and copper (Poole et al., 2004).

The mopane caterpillars consist of 16-20 % of fat (of which 40 % are essential fatty acids), 60-70 % of proteins, around 10 % of mineral substances. The nutrition facts are an approximation (Arnold van Huis et al., 2013).

Preparation

The taste of worms has been compared to salty potatoes chips but it depends on the personal preferences of each consumer. The worms are not similar to potato chips only in taste but also in the way of preparation. Worms are usually consumed simply dried and seasoned with spices (Paper, Makhado, & Africa, 2012).

The first step is commonly drying. The drying process commonly takes place outside on a hard surface. It is a favourable way of preparation because the worms stay edible for longer time than when they remain fresh, so they can be stored for later consumption or sold at markets (Paper et al., 2012). They can be eaten as a starter or served as a side dish. (Zijlma, 2015).

The most popular way of consuming the worms after they have been dried is to fry them with other ingredients such as tomatoes, lot of chillies and other spices, onions or even peanuts (Paper et al., 2012). They are often served along “pap”, a maize porridge.

Other way to prepare worms is to eat them straight away, still fresh so they do not have to be cooked or processed in any other manner to be softened. Served fresh they are less chewy. However it is important to only consume raw worms, if they have been freshly harvested to prevent food poisoning and other digestive complications (Zijlma, 2015).

Mopane worm recipe

Ingredients: 1 cup of salt & 3 cups of fresh mopane worms

Recipe:

Align 4 or 5 worms in both hands & squeeze like milking a cow

Discard liquid guts, Boil worms in salt water until water evaporates (about 30 minutes), Spread worms out on empty bags in the sun, turning every hour until dry (about 1 day), Enjoy.

Figure 6. Preparation of a Mopane worm *(Paper et al., 2012)*

4.3.1.2 Shea defoliator

Shea defoliator *(Cirina forda)* is a type of caterpillar mostly eaten in Western Africa. They are a big article on the local market since they are sold to northern parts of the country. They appear mostly during rainy season, from July to September. For those people who pick them, they represent an essential source of income (Badanaro, Amevoin, Lamboni, & Amouzou,2014).

Table 3. Collecting period of *C. forda* caterpillars during the quarters of the year *(Badanaro et al., 2014)*

	Numbers of involved actors (%)			
Informants	**January-March**	**April-June**	**July-Septembre**	**October-December**
Collectors	0 (0)	0 (0)	100 (33.34)	0 (0)
Resalers	0 (0)	0 (0)	97 (32.3)	3 (1)
Consumers	0 (0)	6 (2)	85 (28.34)	9 (3)
Total	0 (0)	6 (2)	282 (94)	12 (4)

It is common to either sell or eat freshly harvested caterpillars. They are not being preserved for long time. The collectors are usually men, children who help parents or female farmers profiting from selling drinks and food at road sides. Picking take time falls mostly between 4:00 and 5:30 a.m using flashlights. Time spent in the fields depends on

amount of caterpillars under Shea trees where is their natural habitat (Badanaro et al., 2014).

Nutritional value

This caterpillar is famous for its low water content and richness of proteins, fibre and ashes. The fresh ones are richer in nutrition than the converted ones. Same as Mopane caterpillars, Shea caterpillar is rich in minerals such as sodium, potassium, iron, magnesium, calcium and phosphorus. Raw caterpillars are not as rich in sodium. This type of insect contains less copper and zinc. The differences between the state of caterpillars are not significant for the benefits provided for consumers, both forms, raw and converted, are great source of nutrition (Badanaro et al., 2014).

Preparation

After the caterpillars are harvested they are killed by boiling them in water with salt. Afterwards they are roasted and spiced and consumed immediately. To keep them edible and preserve them, they may be moistened with potash liquid prepared from the ashes of Palmyra palm *Borassus aethiopum* Mart. (Arecaceae). Then they can be naturally dried in the sun and stored for up to one year (Badanaro et al., 2014).

4.3.2 Termites

Termites are usually considered a type of insects which are disruptive in the households. Their consumption may provide a solution to two problems, they would no longer cause serious damage and they may provide a valuable food source. This type of insects is rich in proteins, iron, calcium, essential fatty acids and amino acids such as tryptophan and can be found in almost every house (Lallanilla, 2014).

Considering farming them industrially it is very simple, undemanding (neither from financial nor from time aspect). The requirement for the farms are basic cheap materials such as dry sorghum stems or other cereals, water, a piece of an old jute bag, a stone and piece of soil in cool and dark place. They can be harvested in as little as 3-4 weeks (Farina, Demey, & Hardouin, 1991).

4.3.2.1 *Macrotermes bellicosus*

Macrotermes bellicosus is a species of termites which represents the biggest group eaten in Africa. *M. bellicosus* is one of the largest members of the family. They are famous for living in colonies which can grow into colonies of thousands of individuals within a few years. They are commonly mistaken for ants because of their secondary name, white ants. These two spices are not related (Mackean, 2004).

Even though metamorphosis is nothing unusual, most individuals in colonies remain in the stage of nymphs to take on the role of workers or soldiers. Just in time for the rainy season the nymphs go back to metamorphosis and develop reproductive organs and wings. The swarm of mature termites fly off into countryside and start new colonies (Mackean, 2004).

They are considered parasites mostly because of digging the underground tunnels which may weaken plants, causing them to collapse or creating access to fungus and other diseases. For trees, termites pose a threat when they disrupt the phloem which could be fatal for the tree. Cocoa trees, sugar cane, young coconut trees, cotton and wheat plants are among the most infested by termites. There are also other ways how termites endanger agriculture. Mostly they are so unpredictable and threatening because their barely move into the outside world and therefore, their presence is unknown (Resnick, 1997).

Nutritional value

Although it seems unlikely the amount off nutrients in each termite depends on its position in the hierarchy of the colony. Studies show that protein content of the soldiers is higher than that of workers and the queen. But if we consider the amount of sodium, the queen is significantly richer in sodium than soldiers. They are also rich vitamin A and C. Termite workers have the highest vitamin C content, while the queen has the highest vitamin A content (Muanya, 2015).

Table 4. Proximate analysis (%) of dried *Macrotermes bellicosus* (Banjo, Lawal, & Songonuga, 2006)

Insect	**Crude protein (mg)**	**Ether extract (mg)**	**Ash (mg)**	**Crude fibre (mg)**	**Dry matter (mg)**	**Moisture (mg)**	**Nitrogen free extract (mg)**
Macrotermes bellicosus	20.4	28.2	2.9	2.7	90.6	2.82	43.3

Thanks to their high content of nutrients they are a big part of popular medicine. They are used in treatments for influenza, asthma, bronchitis, whooping cough, sinusitis, tonsillitis and hoarseness. Ten species were recorded. They are also used in alternative medicine-sickness of pregnant women and in traditional tribal societies as a charm for spiritual protection (Muanya, 2015).

Preparation

The consumption of termites usually takes place during rainy season. Thanks to the heavy rains, they are forced to crawl out so they can be picked late at night. Basic type of preparation is to fry and season them with available spices. In this form, they are eaten as a snack. Other method which is usually used is grinding termites by stones. This leads to production of termite paste which is then used to make termite bread or can be eaten on its own. Peanuts are used most often to season the termite dishes (Mackean, 2004).

4.3.3 Bugs

This huge group of around 75,000 species is regularly called true bugs. That is because in our society it is routine to call all insects bugs. Some of the members are considered agricultural pests. They feed on almost everything: all kinds of vegetable, fruit and other plants such as soybeans, crops etc. (Schuh & Slater, 1995).

Bugs do not undergo metamorphosis so their young are called nymphs and look similar to the adult bugs. They are adaptable. Their habitat can vary greatly for example they can live in water, actually there is a group of Hemiptera which are called water bugs, others can be seen on dry land, in various climates and environments (Schuh & Slater, 1995).

4.3.3.1 Stink bug

Encosternum delegorguei also known as the big marmorated stink bug. This example comes from Hemiptera order and can be found in diverse ecosystems. Their only requirements tend to be the presence of pines and oaks and big thick layer of hummus in the vicinity (Ramos-Elorduy, 1998). They are easily recognized thanks to their shield of various colours (grey, white, brown, copper, black) which blend into each other. It is considered a delicacy, consumed mostly in South Africa. They are big part of the market and help the harvesters to make reasonable income (Teffo, Toms, & Eloff, 2007).

Bugs are considered agriculture pests. Bugs feed on wide range of plants (peaches, cherrie, pears, raspberries, green beans, soybeans), beginning in late May; early June. They use their sucking system which causes dimpled, creates necrotic areas on the external site of fruits, seed loss, increasing chance of plant pathogens infestation. Stink bugs release specific smell when threatened (Schuh & Slater, 1995).

Nutritional value

Stink bugs are excellent source of proteins, fats, amino acids, minerals and vitamins. Their harvesting and preservation is highly desirable. In dry form their exact content of protein is 35%, 51% of fat, with an energy content of 2600 kJ/100 g. Amino-acid concentrations varied from 0.82 mg/100 g (for threonine) to 1.32 mg/100 g (valine). Mineral content was determined to be 1.2 g/100 g (Teffo et al., 2007).

The high fat content is easily detectable already when you pick them and put them in water, they leave the typical fat maps on the water surface. They are not as rich in proteins as mopane worms but still they are considered as a suitably rich source (Teffo et al., 2007).

Table 5. General composition of Sting bug *(Teffo et al., 2007)*

Protein (%)	**Fat (%)**	**Ash (%)**	**Carbohydrate (g/100 g)**	**Moisture (%)**	**Dry matter (%)**	**Energy (kJ/100 g)**
35.2	50.5	1.7	7.63	4.9	95.1	2600

Table 6. Vitamin composition of Sting bug *(Teffo et al., 2007)*

Vit. A (%)	**Vit. B_1 (%)**	**Vit. B_2 (%)**	**Vit. C (%)**	**Vit. E (%)**
0.23	0.63	0.86	Not detected	2.17

Table 7. Chemical composition of Sting bug *(Teffo et al., 2007)*

Cl (mg)	Na (mg)	Cu (mg)	SO_4 (mg)	Ca (mg)	Mg (mg)	K (mg)	P (mg)	Fe (mg)	Se (mg)	Mn (mg)	Zn (mg)
85.4	55.3	4.4	66.7	91	109	275	575	20.2	0.2	0.8	46

Preparation

Preparation of stink bugs is no different from other insects. They can be eaten live or they can be processed in many ways. The possibilities are endless. They can be deep fried, roasted, sun dried, minced. The taste has been described as very oily. The real taste may be hard to get used to so when locals adjust the stink bugs to pellet of other consumers they use a lot of spices to cover the taste of stink bugs' defense liquid (Boas, 2011).

4.3.4 Grasshoppers

Grasshoppers are pioneers of entomophagy. People think of them first usually when they are asked about edible insects. It is caused by their omnipresence and low requirements for life conditions. They are active during the day, they are not nocturnal animals. Some species can be very good flyers which can fly even hours at once (Singer, 2016).

They are well known for their specific sound which they make by chafing their thighs against their wings. They are also considered pests and are infamous for their destruction of crops. To prevent the crops farmers should create shades in the field because that will discourage the grasshoppers to move that way (Singer, 2016).

4.3.4.1 *Acanthacris ruficornis*

Acanthacris ruficornis can be found through Africa, but is being mostly eaten as food in northern parts of South Africa, Congo and Sahel. They feed on the leaves of wide range of trees, plants and crops. Their habitat is typically an open ground with small trees (Cerritos Flores et al., 2015).

During the year, they produce only one generation. They appear after the first summer rains and reach adulthood in February. The season of adults is from January to September and the peak month is March. Females lay eggs between January and June and during the

winter they undergo diapause and emerge again in the beginning of the next season (A Van Huis, 2003).

They are usually picked in the mornings. Locals have many methods how to harvest them. They make special brooms from leaves which are swept through vegetation which has been cut the day before. Some of the pickers also use smoke to keep down the flying ones (Cerritos Flores et al., 2015).

Nutritional value

The study made by Banjo et al. (2006) set that amount of proteins in grasshoppers is on average 28.28% (29.62, 28.42 and 26.8%), 48.2% and 46.2% fat, 2.8% and 2.6% ash, 3.9% and 4.9% dietary fibre for the green and brown grasshoppers. These also contain minerals such as; phosphorus (P) 140.9 mg/100g and 121.0 mg/100g, potassium (K) of 370.6 mg/100g and 259.7 mg/100g, calcium (Ca) of 27.4 mg/100g and 24.5 mg/100g, iron (Fe) of 16.6 mg/100g and 13.0 mg/100g, zinc of 17.3 mg/100g and 12.4 mg/100g (Banjo et al., 2006).

Table 8. Proximate composition og grasshoppers *(Kinyuru, 2010)*

Analysis	*Ruspolia differens (green)*	*Ruspolia differens (brown)*
Moisture content (%)	$66.4 \pm 0.5_b$	$71.2 \pm 1.0_a$
Ash (%)	$2.8 \pm 0.5_b$	$2.6 \pm 0.4_a$
Crude Protein (%)	$43.1 \pm 0.5_a$	$44.3 \pm 0.7_a$
Crude fat (%)	$48.2 \pm 0.2_a$	$46.2 \pm 0.3_b$
Crude fiber (%)	$3.9 \pm 0.1_a$	$4.9 \pm 0.1_a$

*All values except moisture content expressed as means ± SE on dry weight basis.

*Values on the same row followed by the same letter are not significantly different ($p > 0.05$)n = 6

The results of the study show that grasshoppers are an excellent source of essential minerals, vitamins and nutrients that are necessary for healthy function of the human body. It provides a great solution to the question of food security and nutritional deficiencies that are increasingly becoming a global concern.

Preparation

The first step which is done during preparation is to rip off the wings and legs from the bodies of grasshoppers. The wings are removed because they are very hard and cannot be easily eaten. The legs are removed to prevent obstruction during consumption or if you prepare them alive this step is also done to have better control of the insect. After the removal the bodies are washed in strainer (Arnold Van Huis et al., 2013).

After washing, they are put on a heated pan. No oil is needed because they contain enough fats on their own. They are fried in a manner similar to preparation of chips. They are spiced and seasoned according to personal preferences. This preparation is very simple and the most popular. The grasshoppers are often eaten alive. But that is something common among kids. They are served as a side dish, chips, snack or when you just want something small to nibble on (Obopile & Seeletso, 2013).

5. Conclusion

Alternative sources of animal protein in tropical and subtropical regions of Africa represented by edible insect was studied in this thesis. The study analysed orders and their specific representatives which are eaten and have potential to help ensure the food security in Africa because of their nutrition value. There have been five chosen specimens described into greater detail. The first one was Mopane Caterpillar *(Gonimbrasia belina)*, the second one was Shea defoliator *(Cirina forda)*, the third one was termite *(Macrotermes bellicosus)*, the fourth one was representative of the real bugs *(encosternum delegorguei)*, the fifth last one was representative of grasshoppers *Acanthacris ruficornis*.

The results of this study showed different types of insects which are used as a source of nutritional food throughout Africa. The study described the relationship between Africans and insects and presented specific examples of insects included in the local diets and cuisines. Study made by van Huis (2003), provided a complex review on the use of insects located in Sub-Saharan Africa.

Consumption of insects varies among different countries as well as within one single country among the individual districts. Use of insects for cooking also depends on the cultural and ethnic background of the community. Some species such as Shea defoliator or Cirina moth are commonly eaten in Democratic Republic of Congo and Zambia but they are not part of the Tanzanian or Ugandan cuisine (Kelemu et al., 2015). The taboos and prohibitions involved do not even prevent entomophagy but traditional beliefs influence what is eaten in which region (Ramos-Elorduy, 1998).

This work investigated what kind of insect is eaten where, how it is prepared, its nutritional values, life requirements, different ways of harvesting the insects, preparation and storage, see Table 9 with summarized data. Among the methods of insect collecting (trapping, digging) hand-picking is the most commonly used. Most often reported ways of preparation are roasting, frying, steaming and boiling (van Huis 2003; Nonaka 1996).

Studies showed that insects could become a major part of the diet of people, particularly in western countries if encouraged by cleverly conducted campaigns. One of the biggest obstacles in including more insects into daily diets of local people to improve their nutritional intake is the change in perception of what is acceptable to eat based on western

diets. Modern life led to development of fast food and pre-cooked processed foods which resulted in loss of traditional lifestyles. Majority of people already eating insect claims that insects can easily become a stable source of income, mostly in rural areas and replace meat products regarding their nutritional values (Kelemu et al., 2015).

Entomophagy has been identified as a potential solution for low food security on the African continent for many reasons (nutritional values of insect, cost of the harvesting, low pollution) and therefore should be more popularized in western countries to get rid of the highly influencing "disgusting factor". Nowadays the change in acceptance of insects as a food source is already changing. This shift in perception is urgent but due to affordable travelling and easily accessible information about the advantages of insect consumption insects are becoming more acceptable in some regions even trendy and fashionable. As the demand increases so will the establishment of stable supply. Stable supply may be secured by establishing insect farms based on those already working in some parts of Africa.

6. References

Australian Museum. (2012). Retrieved February 22, 2017, from https://australianmuseum.net.au/bogong-moth

Badanaro, F., Amevoin, K., Lamboni, C., & Amouzou, K. (2014). Edible Cirina forda (Westwood, 1849) (Lepidoptera: Saturniidae) caterpillar among Moba people of the Savannah Region in North Togo: from collector to consumer, *3*(8), 13–26. https://doi.org/10.15590/ajase/2014

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*(1684–5315), 298–301. https://doi.org/10.5897/AJB05.250

Bio-Innovation Zimbabwe. (2016). Mopane worms relish | BIZ. Retrieved April 14, 2017, from http://bio-innovation.org/recipes/mopane-worms-relish/

Boas, S. (2011). What's a stinkbug taste like? Don't ask - tribunedigital-orlandosentinel. Retrieved April 4, 2017, from http://articles.orlandosentinel.com/2011-04-11/news/os-lk-sherry-bias-simply-living-0411120110411_1_stinkbug-mulberries-taste

Bohannan, P., & Curtin, P. D. (1988). *Africa and Africans*. Waveland Press.

Borkovcová, M. et al. (2015). *Hmyz na talíři* (první vydá). Brno: Jota.

Cerritos Flores, R., Ponce-Reyes, R., & Rojas-García, F. (2015). Exploiting a pest insect species Sphenarium purpurascens for human consumption: ecological, social, and economic repercussions. *Journal of Insects as Food and Feed*, *1*(1), 75–84. https://doi.org/10.515/tcs.2010.001

Curtin, P. D. (1995). *African history : from earliest times to independence*. Longman.

Del Toro, I., Ribbons, R. R., & Pelini, S. L. (2012). The little things that run the world revisited: A review of ant-mediated ecosystem services and disservices (Hymenoptera: Formicidae). *Myrmecological News*, *17*(August), 133–146.

Donahue, J. (2013). Mopane Worm from Namibia - What's That Bug? Retrieved April 14, 2017, from https://www.whatsthatbug.com/2013/03/18/67072/

Elvin, C. M., Carr, A. G., Huson, M. G., Maxwell, J. M., Pearson, R. D., Vuocolo, T., … Dixon, N. E. (2005). Synthesis and properties of crosslinked recombinant pro-resilin. *Nature*, *437*(7061), 999–1002. https://doi.org/10.1038/nature04085

Ezengige, G. (2016). Nutritional benefits of eating winged termites ("aku") scientifically known as Macrotermes bellicosus | Health Bubbles. Retrieved April 14, 2017, from http://healthbubbles.com/gb/?p=3132

FAO. (2010). *Forest insects as food: humans bite back. Rap …*. https://doi.org/ISBN 978-92-5-106488-7

Farina, L., Demey, F., & Hardouin, J. (1991). Production de termites pour l´aviculture villageoise au Togo. *Tropicultura*.

Food and Agriculture Organization of the United Nations. (2006). Food security. *Policy*

Brief, (2), 1–60. https://doi.org/10.1016/j.jneb.2010.12.007

Goss, M. (2003). Anacridium. Retrieved April 14, 2017, from http://www.martingoss.co.uk/photogallery/Crickets_hoppers_katydids/Anacridium_sp2.jpg

Guo, X., Dong, Z., Zhang, Y., Li, Y., Liu, H., Xia, Q., & Zhao, P. (2016). Proteins in the Cocoon of Silkworm Inhibit the Growth of Beauveria bassiana. *PloS One*, *11*(3), e0151764. https://doi.org/10.1371/journal.pone.0151764

Halloran, A. (2013). La contribution des insectes à La sécurité alimentaire, aux moyens de subsistance et à l'environnement. *Food and Agriculture Organization*.

Halloran, A., Roos, N., Eilenberg, J., Cerutti, A., & Bruun, S. (2016). Life cycle assessment of edible insects for food protein: A review. *Agronomy for Sustainable Development*, *36*(4), 57. https://doi.org/10.1007/s13593-016-0392-8

Hanboonsong, Y., & Durst, P. B. (2014). *Edible insects in Lao PDR :*

Hobbs, J.-A. (2012). 15 of Africa's favorite dishes | CNN Travel. Retrieved April 13, 2017, from http://travel.cnn.com/15-favourite-dishes-africa-897571/

Huis, A. Van. (2003). INSECTS AS FOOD IN SUB-SAHARAN AFRICA. *Insect Sci. Applic*, *23*(3), 163–185. Retrieved from http://ag.udel.edu/delpha/4434.pdf

Chen, X., Feng, Y., & Chen, Z. (2009). Common edible insects and their utilization in China: INVITED REVIEW. *Entomological Research*, *39*(5), 299–303. https://doi.org/10.1111/j.1748-5967.2009.00237.x

Ingram, B. M., Nabhan, G., & Buchmann, S. (1996). Our Forgotten Pollinators : Protecting the Birds and Bees, 1–12.

Kasperek, L. (2015). Street Food - Fried Grasshoppers Stock. Retrieved April 14, 2017, from https://www.dreamstime.com/stock-photos-street-food-fried-grasshoppers-streets-bangkok-thailand-image40148423

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*(1), 1–17. https://doi.org/10.3920/JIFF2014.0016

Kinyuru, J. N. (2010). Nutritional potential of longhorn grasshopper (. *Journal of Agriculture, Science and Technology*, 32–46.

Lallanilla, M. (2014). 7 Insects You'll Be Eating in the Future. Retrieved March 30, 2017, from http://www.livescience.com/43901-eating-insects-bugs-entomophagy.html

Lenteren, J. C. Van. (2006). Ecosystem services to biological control of pests : why are they ignored ?, *17*, 103–111.

Looy, H., Dunkel, F. V., & Wood, J. R. (2013). How then shall we eat? Insect-eating attitudes and sustainable foodways. *Agriculture and Human Values*, 1–11. https://doi.org/10.1007/s10460-013-9450-x

Mackean, D. G. (2004). Termites, Macrotermes. Life-cycle, economic importance, prevention of damage. Biology article by D G Mackean. Retrieved from http://www.biology-resources.com/termite-01.html

Moore, A. (2014). Atlanta Black Star. Retrieved September 30, 2014, from http://atlantablackstar.com/2014/09/30/6-ways-africa-exploited-europeans-asian-neo-colonists/3/

Muanya, C. (2015). Dietary, medicinal values of termites explored — Features — Breaking News, Nigeria News and World News – The Guardian Nigeria. Retrieved April 1, 2017, from https://guardian.ng/features/dietary-medicinal-values-of-termites-explored/

Munthali, S. M., & Mughogho, D. E. C. (1992). Economic incentives for conservation: beekeeping and Saturniidae caterpillar utilization by rural communities. *Biodiversity and Conservation*, *1*(3), 143–154. https://doi.org/10.1007/BF00695912

Mwaniki, A. (2006). Achieving Food Security in Africa: Challenges and Issues.

Nation, U. (2014). The Millenium Development Goals Report 2014, 32. https://doi.org/10.1177/1757975909358250

Newman, J. L., & Rogers D. Spotswood Collection. (1995). *The peopling of Africa : a geographic interpretation*. Yale University Press.

Obopile, M., & Seeletso, T. G. (2013). Eat or not eat: An analysis of the status of entomophagy in Botswana. *Food Security*, *5*(6), 817–824. https://doi.org/10.1007/s12571-013-0310-8

Paper, C., Makhado, R., & Africa, S. (2012). Mopane worms, (May 2014).

Payne, C. (2016). Blog Posts - Charlotte LR Payne. Retrieved April 14, 2017, from http://www.libertyruth.com/blog/previous/2

Poole, N., Frost, P., Stack, J., & Madzara, A. (2004). Mopane woodlands and the Mopane worm : Enhancing Rural Livelihoods and Resource Sustainability. *Wild*, (November), 4–7.

Population Reference Bureau. (2016). *2016 World Population Data Sheet*. https://doi.org/10.2307/1972177

Ramos-Elorduy, J. (1998). Creepy Crawly Cuisine: The Gourmet Guide to Edible Insects - Julieta Ramos-Elorduy, Ph.D. - Knihy Google. Retrieved from https://books.google.cz/books?hl=cs&lr=&id=XMlrAwAAQBAJ&oi=fnd&pg=PP8&dq=edible+stink+bug+recipe&ots=YSntXSf328&sig=0agz7HlqvMou9osYuNZaPb6zWKs&redir_esc=y#v=onepage&q=edible stink bug recipe&f=false

Ramos-Elorduy, J. (2006). Threatened edible insects in Hidalgo, Mexico and some measures to preserve them. *Journal of Ethnobiology and Ethnomedicine*, *2*(51), 1–10. https://doi.org/10.1186/1746-4269-2-51

Ramos-Elorduy, J. (2010). Edible insects as a natural resource. In *Edible insects: Future prospects for food and feed security* (pp. 45–58). Retrieved from www.fao.org/docrep/018/i3253e/i3253e.pdf

Reader, J., & Rogers D. Spotswood Collection. (1998). *Africa : a biography of the continent*. A.A. Knopf.

Resnick, M. (1997). Turtles, Termites, and Traffic Jams: Explorations in Massively Parallel Microworlds (Complex Adaptive Systems). *Cambridge MA MIT Press*,

(1997), 181. Retrieved from http://scholar.google.com/scholar?q=turtles+termites&hl=it&btnG=Cerca&lr=#2

Saeed, T., Abu Dagga, F., & Saraf, M. (1993). Pesticides in Locust.pdf. Kuwait: Central Analytical Laboratory, Kuwait Institute for Scientific Research.

Schuh, R. T., & Slater, J. A. (1995). True Bugs of the World (Hemiptera:Heteroptera): Classification and Natural ... - Randall T. Schuh, James Alexander Slater - Knihy Google. Retrieved from https://books.google.cz/books?hl=cs&lr=&id=wmSc-2KDmZ4C&oi=fnd&pg=PR11&dq=hemiptera&ots=6sJpl42HfA&sig=caXFl0taDxmyhPVlUtz7f2xLdbk&redir_esc=y#v=onepage&q=hemiptera&f=false

Singer, S. S. (2016). Grasshoppers. Retrieved from https://eds-a-ebscohost-com.infozdroje.czu.cz/eds/delivery?sid=d75dd326-d52b-4df2-a924-54feba756b85%40sessionmgr4007&vid=6&hid=4210&ReturnUrl=https%3A%2F%2Feds.a.ebscohost.com%2Feds%2Fdetail%2Fdetail%3Fsid%3Dd75dd326-d52b-4df2-a924-54feba756b85%2540sessio

Siriamornpun, S., & Thammapat, P. (2008). Insects as a Delicacy and a Nutritious Food in Thailand. *Using Food Science and Technology to Improve Nutrition and Promote National Development*, 1–11.

Spooner, S. (2014). Mail & Guardian Africa. Retrieved from http://mgafrica.com/article/2014-07-11-africas-20-most-popular-foods

Steven, J. (2015). Brown Marmorated Stink Bug. Retrieved April 14, 2017, from http://ento.psu.edu/extension/factsheets/brown-marmorated-stink-bug

Teffo, L. S., Toms, R. B., & Eloff, J. N. (2007). Preliminary data on the nutritional composition of the edible stink-bug, Encosternum delegorguei Spinola, consumed in Limpopo province, South Africa. Retrieved from http://www.scielo.org.za/pdf/sajs/v103n11-12/a0310312.pdf

Termite Web. (2012). The Macrotermes termites - Termite Web. Retrieved April 14, 2017, from https://www.termiteweb.com/the-macrotermes-termites/

United Nations. (2015a). The Millennium Development Goals Report. *United Nations*, 72. https://doi.org/978-92-1-101320-7

United Nations. (2015b). *World Population Prospects: The 2015 Revision, Key Findings and Advance Tables.*

van Huis, A., Itterbeeck, J. Van, Klunder, H., Mertens, E., Halloran, A., Muir, G., & Vantomme, P. (2013). *Edible insects. Future prospects for food and feed security*. *Food and Agriculture Organization of the United Nations* (Vol. 171). https://doi.org/10.1017/CBO9781107415324.004

Van Huis, A., Van Itterbeeck, J., Klunder, H., Mertens, E., Halloran, A., Muir, G., & Vantomme, P. (2013). 13. Promoting insects as feed and food. *Edible Insects: Future Prospects for Food and Feed Security*, 141–152. Retrieved from http://www.fao.org/docrep/018/i3253e/i3253e13.pdf

Vantomme, P., Göhler, D., & N'Deckere-Ziangba, F. (2004). Contribution of forest insects to food security and forest conservation: The example of caterpillars in Central Africa. *ODI Wildlife Policy Briefing*, (3), 1–4. Retrieved from

http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/3306.pdf

Wursten, B. (2017). Flora of Zimbabwe: Insect details: individual images: Cirina forda image2. Retrieved April 14, 2017, from http://www.zimbabweflora.co.zw/speciesdata/insect-image.php?insect_id=400510&image_id=2

Yates-Doerr, E. (2015). The world in a box? Food security, edible insects, and "One World, One Health" collaboration. *Social Science and Medicine, 129,* 106–112. https://doi.org/10.1016/j.socscimed.2014.06.020

Zijlma, A. (2015). Mopane Worms - Nutritious and Delicious? Retrieved March 22, 2017, from http://goafrica.about.com/od/botswana/ss/Mopane-Worm.htm

Appendix 1

Figure 7. . Mopane caterpillar *(Donahue, 2013)*

Figure 8. Dried Mopane caterpillars without intestines *(Bio-Innovation Zimbabwe, 2016)*

Figure 9. ***Cirina forda*** *(Wursten, 2017)*

Figure 10. Plate of ***Shea defoliator*** *(Payne, 2016)*

Figure 11. ***Macrotermes bellicosus*** *(Termite Web, 2012)*

Figure 12. Selling of ***Macrotermes Bellicosus*** *(Ezengige, 2016)*

Figure 13. Stink Bug *(Steven, 2015)*

Figure 14. ***Acanthacris ruficornis*** *(Goss, 2003)*

Figure 15. Fried grasshoppers *(Kasperek, 2015)*

Appendix 2

Table 9. Summary of edible insects in Africa *(Kelemu et al., 2015; Banjo et al., 2006; FAO, 2010)*

Insect	Latin name	Local name	Order	Family	Location	Preparation
Stink bug	*Encosternum delegorguei*	Harurwa, Harurgwa	Hemiptera	Tessaratomidae	South Africa, Swaziland, Mozambique, Malawi Zimbabwe, Botswana, Namibia	Boiled
Mopane worm	*Gonimbrasia belina*	Phane, Mashonja, Omangungu	Lepidoptera	Satumiidae	Democratic Republic of Congo (DRC), Zambia, South Africa, Zimbabwe, Botswana, Malawi	dried, smoked, fresh, juiced
Cabbage tree emperor moth	*Bunaea alcinoë*	Kiepersolpouoogmot	Lepidoptera	Satumiidae	DRC, Zambia, South Africa, Cameroon, Congo, Central African Republic (CA Republic), Zimbabwe, Nigeria, Tanzania	dried, smoked
Urota moth	*Urota sinope*	Motte	Lepidoptera	Satumiidae	DRC, South Africa, Zimbabwe, Botswana, Gabon, Mozambique, Namibia	dried, smoked
Cirina moth	*Cirina butyrospermi*	Situmu	Lepidoptera	Satumiidae	DRC, Zambia, South Africa, Zimbabwe, Burkina Faso, Nigeria, Mali, Ghana	dried, smoked
Shea defoliator	*Cirina forda*	Vlinder	Lepidoptera	Satumiidae	DRC, Zambia, South Africa, Botswana, Burkina Faso, Nigeria, Mozambique, Namibia, Ghana, Togo, Chad	dried, smoked

Table 10. (Continued)

Insect	Latin name	Local name	Order	Family	Location	Preparation
Bush cricket	*Ruspolia differens*	Ire	Orthoptera	Tettigoniidae	DRC, Zambia, South Africa, Cameroon, Zimbabwe, Kenya, Uganda, Tanzania, Malaw	dried, smoked
Grasshopper	*Acanthacris ruficornis*	Tata	Orthoptera	Acrididae	DRC, Zambia, South Africa, Cameroon, Congo, CA Republic, Zimbabwe, Burkina Faso, Malawi, Mali, Niger, Togo, Benin	dried, smoked, fresh
Migratory locust	*Locusta migratoria migratorioides*	Wewe	Orthoptera	Acrididae	Zambia, Cameroon, Congo, Zimbabwe, Sudan, South Sudan	dried,smoked
African field-cricket	*Gryllus bimaculatus*	Abuzu	Orthoptera	Gryllidae	Guinea Bissau, Sierra Leone, Guinea, Liberia, Benin, Togo, Nigeria, DRC, Kenya, South, Sudan, Zambia	dried, smoked
Palm weevil	*Rhynchophorus phoenicis*	Akpa-nkwu	Coleoptera	Curculionidae	DRC, Cameroon, Congo, CA Republic, Nigeria, Angola, Ivory Coast, Niger, Sao Tomé, Guinea, Togo, Liberia, Benin, Guinea Bissau	boiled
Rhinoceros beetle	*Oryctes boas*	Ebe	Coleoptera	Scarabaeidae	Nigeria, Ivory Coast, Sierra Leone, Guinea, Liberia, Guinea Bissau DRC, Congo, South Africa, Botswana, Namibia	boiled

Table 11. (Continued)

Insect	Latin name	Local name	Order	Family	Location	Preparation
Termite	*Macrotermes bellicosus*	Esusu	Isoptera	Termitidae	DRC, Cameroon, Congo, CA Republic, Nigeria, Côte d'Ivoire, Kenya, Sao Tomé, Guinea, Togo, Liberia, Guinea Bissau, Burundi	fried, dried
Termite	*Macrotermes natalensis*	Esusu	Isoptera	Termitidae	DRC, Cameroon, Congo, CA Republic, Nigeria, Burundi, South Africa, Zimbabwe, Nigeria, Malawi	fried, dried
Termite	*Macrotermes*	Esusu	Isoptera	Termitidae	DRC, Zambia, Zimbabwe, Nigeria, Tanzania, Malawi, Senegal, Uganda, Côte d'Ivoire, Guinea, Ghana, Togo, Burundi, Benin	fried, dried
Honey bee	*Apis mellifera mellifera*	Oyin	Hymenoptera	Apidae	DRC, Zambia, Botswana, Nigeria, Tanzania, Senegal, Sierra Leone, Ghana, South Sudan, Togo, Lesotho, Benin	fresh, cooked
African honey bee	*Apis mellifera adansoni*	Oyin	Hymenoptera	Apidae	DRC, Zambia, CA Republic, Nigeria, Tanzania, Sierra Leone, Ghana, Benin	dried
Ant	*Carebara vidua*	Mier	Hymenoptera	Formicidae	DRC, Zambia, South Africa, Zimbabwe, Botswana, Malawi, Sudan, Kenya, South Sudan	fried, dried

Table 12. (Continued)

Insect	Latin name	Local name	Order	Family	Location	Preparation
Ant	*Carebara lignata*	Mier	Hymenoptera	Formicidae	Zambia, South Africa, Zimbabwe, Botswana, Sudan, Mozambique, Namibia, South Sudan	fried, dried
Desert locust	*Schistocerca gregaria*	Tsie ya sekala	Orthoptera	Acrididae	Zambia, South Africa, Cameroon, Congo, Botswana, Tanzania, Sudan, Uganda, Ethiopia, Kenya, Sierra Leone, Morocco, Guinea, Lesotho, Mauritania, Somalia, Eritrea, Guinea Bissau	dried, smoked, fried