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**Sudan University of Science and Technology**  
**College of Graduate Studies**

**Locust( *SchistocercaGregaria*) as an Alternative Source of Protein Compared  
with Other Conventional Protein Sources**

الجراد(*Schistocerca Gregaria*) كمصدر بديل للبروتين مقارنة مع مصادر البروتين التقليدية  
الأخرى

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## الآية

وَأَفْسَدِ رَأْيَ اللَّهِ عَمَلَكُمْ وَرَسُولَهُ وَالْمُؤْمِنُونَ وَسَدُّوا دُونَ إِيَّاهِ  
عَالَمِ الْغَيْبِ وَالشَّهَادَةِ فَيُنَبِّدُكُمْ كَمَا تَكُونُونَ (

التوبة (105)

## **DEDICATION**

I dedicate this work to my beloved father

Mohamed Khalil

and to my dearest mother

Samira Ahmed

for their endless love, support and encouragement.

They have successfully made me the person I am becoming .

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## ABSTRACT

The present study was carried out to estimate the nutritional composition of the desert locust (*Schistocerca gregaria*), and its potentials as a protein source compared with other conventional sources of protein. The samples brought from south kordofan, al gadarf and northern state, all samples were sun dried firstly before the tests carried out. The proximate analyses results of the locust revealed that the protein content was  $50.55 \pm 0.24\%$ , the fat content was  $27.95 \pm 1.068\%$ , the fiber content was  $10.2 \pm 0.191\%$ , the ash content was  $4.74 \pm 0.27\%$ , the moisture content was  $6.44 \pm 0.75\%$  and the available carbohydrate content was  $0.017 \pm 0.00424\%$ .

Locust also contain considerable amount of essential minerals the sodium content was  $2813.6 \pm 32.0$  (mg/kg), the content of potassium was  $2480.4 \pm 23.3$  (mg/kg), the calcium content was  $257.1 \pm 38.5$  (mg/kg), the magnesium content was  $346 \pm 17.3$  (mg/kg), the iron content was  $29.25 \pm 5.9$  (mg/kg) it was found to be the less amount.

The protein content of locust showed no significance difference compared to beef, but in case of some other protein sources (egg, chicken, wheat flour, bean) the locust has higher value, the results evidently, indicated that locust has high nutritional value and can be considered as an alternative protein source.

## الملخص

هدفت هذه الدراسة إلى تقدير التركيبة الغذائية للجراد الصحراوي وإمكانية جعله مصدراً بديلاً للبروتين مقارنة مع بعض مصادر البروتين التقليدية الأخرى. أحضرت العينات من جنوب كردفان، القضارف و الولاية الشمالية و تم تجفيف العينات بالشمس قبل البدء بإجراء الاختبارات. وقد أظهرت نتائج التحليل التقريبي أن محتوى البروتينين  $0.28 \pm 50.55\%$  ومحتوى الدهون  $1.068 \pm 27.95\%$  ومحتوى الألياف كان  $0.191 \pm 10.23\%$ ، ومحتوى الرماد  $0.27 \pm 4.74\%$ ، ومحتوى الرطوبة  $0.75 \pm 6.44\%$  وكان محتواه من الكاربوهيدرات  $0.004 \pm 0.017\%$ .

كما يحتوي الجراد على كمية كبيرة من المعادن الأساسية، فمحتواه من الصوديوم  $2813.6 \pm 32.0$  مليجرام/كجم ، ومحتوى البوتاسيوم  $2480.4 \pm 23.3$  مليجرام/كجم، محتوى الكالسيوم  $257.1 \pm 38.5$  مليجرام/كجم و محتواه من الماغنسيوم  $346 \pm 17.3$  كان مليجرام/كجم أما محتوى الحديد  $29.25 \pm 5.9$  مليجرام/كجم كان الأقل كمية.

كما أن محتوى البروتين في الجراد مقارنة مع لحوم البقر لم يكن هناك أي فرق معنوي، ولكن في حالة مصادر البروتين الأخرى (البيض، الدجاج، دقيق القمح و الفول المصري) الجراد كان له القيمة الأعلى. النتائج تشير بوضوح علي أن الجراد ذا محتوى تغذوي عالي ويمكن اعتباره مصدراً بديلاً للبروتين.

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## **CHAPTER ONE**

### **INTRODUCTION**

It is well known that many current food production systems are not sustainable in a global perspective, the struggle to mitigate the effects of land clearing for agricultural use, loss of natural habitats, global warming, use of pesticides and health and welfare issues in animal production systems will continue unless major changes are made (Jansson and Berggren, 2015).

The global meat production has doubled between 1980 and 2007 from 136.7 to 285.7 million tons (FAO, 2009), and in the near future the need of proteins will not be fulfilled by available protein sources of animals (Sathe, 2015).

Consequently the world needs more protein source to feed a growing and underfed population to solve this problem there are many solutions, one of the solutions is use the insect ( Boland, 2013).

Hence, insect rearing for entomophagy seems to fit it perfectly with a modern food production system ,due to the high resource efficiency and good nutritional value of insects (Jansson and Berggren, 2015) .

This study focus on locust (*Schistocerca gregaria* ), which are insect of the order Orthoptera, many of species of locusts are consumed worldwide for human food in Africa, South America and Asia , they are eaten at home or in restaurants, both in rural and urban areas (Heuzé and Tran, 2016).

Professor Arnold van Huis said: "Producing a kilogram of meat from a cow requires 13kg of vegetable matter as feed , yet 1kg of meat from a cricket, locust or beetle needs just 1.5 to 2kg of fodder, and produces a fraction of the CO<sub>2</sub> emissions, the good news is that, not only do insects require less food to farm, you also don't have to eat as much to survive, as they are an extremely good source of protein and vitamins " (Insect farmer, 2010)

Locust (*Schistocerca gregaria*) one of the most commonly used insect as a food, locust (*Schistocerca gregaria*) is considered one of the clean sources of protein because it feeds on green plants only of herbs and different trees.

Locust (*Schistocerca gregaria*) permissible in divine religions Jewishness, Christianity and in Islam. In Islam it is said that the wives of the Prophet Mohammed peace be upon him gave locust dishes as present.

In Sudan locust (*Schistocerca gregaria*) widely consumed because Sudan consider as spread and propagation area of locusts (*Schistocerca gregaria*), eating locusts usually is prevalent and preferences for the Sudanese in rain field area due to its palatable taste and low price and it is sold in many popular market at the terminal of the capital.

**General objective:**

To evaluate the nutritional value of locust (*Schistocerca gregaria*) compared with conventional sources of protein

**Specific objectives:**

1. To determine the proximate chemical analysis of locust (*Schistocerca gregaria*) and beef.
2. To compare the protein content with the protein content of beef, chicken, egg, wheat flour and beans.
3. To determine the minerals content of locust (*Schistocerca gregaria*).

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1. Introduction**

In near future, there would be tremendous scarcity of sources of animal proteins and protein food requirement will be the top priority (Sathe, 2015) .

Approximately 843 million people worldwide are hungry and a greater number suffer from nutrient deficiencies approximately one billion people have inadequate protein intake, consuming the required amounts of protein is fundamental to human growth and health (Wu *et al.*, 2014 ) .

Livestock production accounts for 70% of all agricultural land ,the global demand for livestock products is expected to almost double by 2050 (Sathe, 2015) .

Insect farming has been suggested as a good alternative to conventional livestock farming for future food production ( Jansson and Berggren, 2015).

#### **2.2. Insects**

The practice of consuming insects is called entomophagy, from the Greek éntomon, insect, and phagein, to eat (Jansson and Berggren, 2015) .

Belluco and other on (2013) found that insects could be great interest as a possible solution due to their capability to satisfy 2 different requirements:

- (i) they are an important source of protein and other nutrients .
- (ii) their use as food has ecological advantages over conventional meat and in the long run economic benefits .

Simultaneously, it reduces the risk of cholesterol and heart failure, as human diet insects contain very rich proteins, fats, carbohydrates, minerals, amino acids, vitamins and fibers therefore, diversity distribution, suitability as human food, cooking methods (Sathe, 2015).

Insects are part of the diet of at least two billion people in the world and more than 1900 insect species are currently used as food (Jansson and Berggren, 2015) .

**Table 1 : Average available food energy in different world regions in kcal per person and per day.**

	<b>1969-71</b>	<b>1999-01</b>	<b>2015</b>	<b>2050</b>
<b>Sub-Sahara Africa</b>	2100	2194	2420	2830
<b>Northern Africa / Middle East</b>	2382	2974	3080	3190
<b>Latin America</b>	2465	2836	2990	3200
<b>Southern Asia</b>	2066	2392	2660	2980
<b>East Asia and Southeast Asia</b>	2012	2872	3110	3230
<b>Transition countries</b>	3323	2900	3020	3270
<b>Industrial countries</b>	3046	3446	3480	3540

Source: Schmidinge, (2012).

### **2.3. Major groups of edible insects**

According to Pal and Roy (2014) the most common insects consumed are beetles (Coleoptera), beside this other groups of edible insects are :

- 1) Lepidoptera caterpillar
- 2) Hymenoptera bee , wasp .
- 3) Orthoptera locust,cricket,grasshopper .
- 4) Hemiptera-true bugs, cicadas, leafhoppers, plant hoppers, scale insects.
- 5) Isoptera termites .
- 6) Odonata dragonfly .
- 7) Diptera flies .

### **2.4. Nutritional value of insects for human consumption**

Insects at all life stages are rich sources of animal protein , insects are an alternative source of protein .

Chitin, and polysaccharide presence in the exoskeleton of insects, which may have a positive effect on the immune system ,usually it is found as

complex compound composed of chitin combined with cuticular proteins, lipids and minerals (Jayaprakash *et al.*, 2016).

Insect meals compared to fish meal contain a lower amount of methionine and calcium which has to be considered when formulating diets based on insect proteins (Jayaprakash *et al.*, 2016).

According to Shrivastava (1993) insect diet is advantageous to humans since it has high caloric and rich nutritive values containing proteins, amino acids, fats, minerals and vitamins and better food convertibility.

#### **2.4.1 Dietary energy**

In Mexico, Oaxaca State 78 insect species analyzed and determined that caloric content was 293–762 kilocalories per 100 g of dry matter (FAO, 2013).

#### **2.4.2 Protein**

In (2010) Xiaoming and other scientist evaluated the protein content of 100 species from a number of insect orders (Table 3).

Protein content was in the range 13–77 percent of dry matter and that there was large variation between and within insect orders, protein content is high in insects and therefore using insects as food can help increase dietary quality when including animal source proteins (Xiaoming, 2010).

The protein content of insects also varies strongly by species, some insects compare favorably with mammals, reptiles and fish, protein content also depends on the feed (e.g. vegetables, grains or waste) (FAO, 2013).

Grasshoppers in Nigeria that are fed with bran, which contains high levels of essential fatty acids, have almost double the protein content of those fed on maize, also the protein content of insects also depends on the metamorphosis stage, adults usually have higher protein content than instars (Ademolu *et al.*, 2010).

Charlton (2016) describe the characteristics of insects protein :

- Highly efficient.

- Natural component of animal diets including; fish, birds, reptiles and mammals .

Table 2: Nutrient composition of different insect meals.

<b>Insects</b>	<b>Item (per kg DM)</b>	<b>Gross energy, MJ</b>	<b>Crude protein, g</b>	<b>Crude fat, g</b>	<b>Crude fiber, g</b>	<b>Ash, g</b>
<b>Field cricket</b> <b>(Gryllus assimilis)</b>	Imago	21.6	564	238	70	64
	Subimago	19.3	638	168	94	54
<b>Housefly</b> ( <i>Musca domestica</i> )	Pupae	20.1	630-762	144-161	157	55-98
	Larvae	20-24	380-604	90-260	16-86	31-173
<b>Black soldier fly</b> <b>(Hermetia illucens)</b>	Larvae	22.1	441-450	150-350	70	146-284
<b>Mealworm</b> <b>(Tenebrio molitor)</b>	Larvae	26.8-27.3	451-603	250-431	51-88	10-45

Source: Jayaprakash *et al.* (2016).

- Protein digestibility higher than most .

**Table 3: Crude protein content, by insect order.**

Insect order	Stage	Range (% protein)
Coleoptera	Adults and larvae	23 – 66
Lepidoptera	Pupae and larvae	14-68
Hemiptera	Adults and larvae	42 – 74
Homoptera	Adults, larvae and eggs	45 – 57
Hymenoptera	Adults, pupae, larvae and eggs	13 – 77
odonata	Adults and naiad	46 – 65
orthoptera	Adults and nymph	23 – 65

Source: FAO ,(2013).

### **2.4.3 Amino acids**

Cereal proteins that are key staples in diets around the world are often low in lysine and, in some cases, lack the amino acids tryptophan (e.g. maize) and threonine( Bukkens, 2005) .

In some insect species, these amino acids are very well represented .

For example, several caterpillars of the Saturniidae family, palm weevil larvae and aquatic insects have amino acid scores for lysine higher than 100 mg amino acid per 100 g crude protein, yet in order to make recommendations regarding the use of edible insects as food enrichments in diets, it is important to look at traditional diets in their entirety, and in particular at staple foods, and to compare their nutritional quality against that of edible insects locally available in the region ,in countries ( Bukkens, 2005) .

In Africa where maize is a staple food – such as Angola, Kenya, Nigeria and Zimbabwe – there are occasionally widespread tryptophan and lysine deficiencies; supplementing diets with termite species like *Macrotermes bellicosus* (Angola)

should be a relatively easy step, as they already form accepted parts of traditional diets, not all termite species are suitable, however: *Macrotermes subhyalinus*, for example, is not rich in these amino acids( Sogbesan and Ugwumba,2008).

#### **2.4.4 Fat content**

Fat is the most energy-dense macronutrient in food , it consists of triglycerides, which all have a glycerol molecule and three fatty acids in their molecular makeup , their oils are rich in polyunsaturated fatty acids and frequently contain the essential linoleic and  $\alpha$ -linolenic acids , the nutritional importance of these two essential fatty acids is well recognized, mainly for the healthy development of children and infants (Michaelsen *et al* ,2009).

Greater attention has been paid to the potential deficient intake of these omega-3 and omega-6 fatty acids in recent times, and insects could play an important role, in particular in landlocked developing countries with lower access to fish food sources, by supplying these essential fatty acids to local diets(Roos *et al* , 2010).

The fatty acid composition of insects appears to be influenced by the plants on which they feed (Bukkens, 2005).The presence of unsaturated fatty acids will also give rise to rapid oxidation of insect food products during processing, causing them to go rancid quickly (FAO,2013).

#### **2.4.5 Micronutrients**

Micronutrients – including minerals and vitamins – play an important role in the nutritional value of food , micronutrient deficiencies, which are common place in many developing countries, can have major adverse health consequences, contributing to impairments in growth, immune function, mental and physical development and reproductive outcomes that cannot always be reversed by nutrition interventions (FAO,2011).

In insects metamorphic stage and diet highly influence nutritional value, making all-encompassing statements on the micronutrient content of insect species of little

value , moreover, the mineral and vitamin contents of edible insects described in the literature are highly variable across species and orders (Roos.N, 2012).

Consumption of the entire insect body generally elevates nutritional content , study on small fish, for example, suggested that consuming the whole organism – including all tissues – is a better source of minerals and vitamins than the consumption of fish fillets , in much the same way, consuming the entire insect is expected to provide higher micronutrient content than eating individual insect parts (Roos.N, 2012).

#### **2.4.6 Minerals**

Minerals play an important part in biological processes , the recommended dietary allowance (RDA) and adequate intake are generally used to quantify suggested daily intake of minerals (Bukkens, 2005)..

Table (4) compares the RDA of minerals for a 25-year-old male with those provided by the *mopane caterpillar*, from the table, it is clear that the *mopane caterpillar* – like many edible insects – is an excellent source of iron ,most edible insects boast equal or higher iron contents than beef ( ) .

Beef has an iron content of 6 mg per 100 g of dry weight, while the iron content of the *mopane capterpillar*, for example, is 31–77 mg per 100 g , the iron content of locusts (*Locusta migratoria*) varies between 8 and 20 mg per 100 g of dry weight, depending on their diet ( Oonincx *et al* ,2010).

Edible insects are undeniably rich sources of iron and their inclusion in the daily diet could improve iron status and help prevent anemia in developing countries (FAO,2013). WHO has flagged iron deficiency as the world's most common and widespread nutritional disorder , in developing countries, one in two pregnant women and about 40 percent of preschool children are believed to be anemic (FAO,2013).

Health consequences include poor pregnancy outcomes, impaired physical and cognitive development, increased risk of morbidity in children and reduced work

productivity in adults , anemia is a preventable deficiency but contributes to 20 percent of all maternal deaths, given the high iron content of several insect species, further evaluation of more edible insect species is warranted (FAO/WHO,2001).

Zinc deficiency is another core public health problem, especially for child and maternal health , zinc deficiencies can lead to growth retardation, delayed sexual and bone maturation, skin lesions, diarrhea, alopecia, impaired appetite and increased susceptibility to infections mediated via defects in the immune system (FAO/WHO,2001)..

In general, most insects are believed to be good sources of zinc, beef averages 12.5 mg per 100 g of dry weight, while the palm weevil larvae (*Rhynchophorus phoenicis* ), for example, contains 26.5 mg per 100 g (Bukkens,2005).

#### **2.4.7 Vitamins**

Vitamins essential for stimulating metabolic processes and enhancing immune system functions are present in most edible insects (FAO,2013).

Bukkens (2005) showed for a whole range of insects that thiamine (also known as vitamin B1) an essential vitamin that acts principally as a co- enzyme to metabolize carbohydrate into energy) ranged from 0.1 mg to 4 mg per 100 g of dry matter .

Riboflavin (also known as vitamin B2, whose principle function is metabolism) ranged from 0.11 to 8.9 mg per 100 mg, by comparison, wholemeal bread provides 0.16 mg and 0.19 mg per 100 g of B1 and B2, respectively (FAO,2013).

Vitamin B12 occurs only in food of animal origin and is well represented in mealworm larvae, *Tenebrio molitor* (0.47 µg per 100 g) and house crickets, *Acheta domesticus* (5.4 µg per 100 g in adults and 8.7 µg per 100 g in nymphs , nevertheless, many species have very low levels of vitamin B12, which is why more research is needed to identify edible insects rich in B vitamins (Bukkens,2005).

Retinol and  $\beta$ -carotene (vitamin A) have been detected in some caterpillars, including *Imbrasia* (=Nudaurelia) *oyemensis*, *I. truncata* and *I. epimethea*; values ranged from 32  $\mu\text{g}$  to 48  $\mu\text{g}$  per 100 g and 6.8  $\mu\text{g}$  to 8.2  $\mu\text{g}$  per 100 g of dry matter for retinol and  $\beta$ -carotene, respectively, the levels of these vitamins were less than 20  $\mu\text{g}$  per 100 g and less than 100 per 100 g in yellow mealworm larvae, superworms and house crickets (Finke,2002).

Generally, insects are not the best source of vitamin A, Vitamin E featured in the palm weevil larvae, for example, which boasts 35 mg and 9 mg per 100 g of  $\alpha$ -tocopherol and  $\beta+\gamma$  tocopherol, respectively; the daily recommended intake is 15 mg, the vitamin E content in ground and freeze-dried silkworm powder (*Bombyx mori*) is also relatively high at 9.65 mg per 100 g (Tong Yiu and Liu, 2011).

**Table 4: Recommended intake of essential minerals per day compared with the mopane caterpillar (*Imbrasia belina*)**

<b>Mineral Intake</b>	<b>recommendation for 25-year-old males (mg per day )*</b>	<b>Mopane caterpillar (mg per 100 g dry weight)</b>
<b>Potassium</b>	4700	1032
<b>Chloride</b>	2 300	-
<b>Sodium</b>	1 500	1 024
<b>Calcium</b>	1 000	174
<b>Phosphorus</b>	700	543
<b>Magnesium</b>	400	160
<b>Zinc</b>	11	14
<b>Iron</b>	8	31

Note:\*Dietary reference intakes (DRIs): recommended dietary allowances and adequate intakes, minerals, Food and Nutrition Board, Institute of Medicine, National Academies.

Source: FAO, (2013)

#### **2.4.8 Fiber content**

Insects contain significant amounts of fiber, as measured by crude fiber, acid detergent fiber and neutral detergent fiber , the most common form of fiber in insects is chitin, an insoluble fiber derived from the exoskeleton. A significant amount of data is available on the fiber content of insects, but it has been produced by various methods and is not easily comparable( Klunder.H, 2012).

Finke (2002) ,estimated the chitin content of insect species raised commercially as food for insectivores, and found it to range from 2.7 mg to 49.8 mg per kg (fresh) and from 11.6 mg to 137.2 mg per kg (dry matter) .

Chitin, the main component of the exoskeleton of an insect, is a long-chain polymer of N-acetyl glucosamine – a derivative of glucose , chitin is much like the polysaccharide cellulose found in plants, which is largely believed to be indigestible by humans, although chitinase has been found in human gastric juices (Paoletti *et al* ,2007).

Chitinase activity is more prevalent in tropical countries where insects are regularly consumed; there may be a lower rate of chitinase activity in Western countries due to the absence of chitin in the diet. Some argue that chitin acts like a dietetic fiber and this could imply a high-fiber content in edible insects, especially species with hard exoskeletons (Bukkens,2005).

#### **2.4.9. Nutritional value of beef versus insects: an example of the mealworm**

Finke (2002) explored the nutritional value of several insect species, including the yellow mealworm (*Tenebrio molitor*) , the larvae of the beetle have been mentioned as a promising option for mass rearing in Western countries because the species is endemic in temperate climates and easy to farm on a large scale, it

has a short life cycle, and farming expertise is already available, particularly in the pet food industry .

In the study by Finke (2002), insects were fasted for 24 hours to void their intestinal tract, the following conclusions were made (on a dry weight basis except for moisture and energy):

Macronutrient composition: the fat content of beef is higher than that of mealworm larvae.

Beef has slightly lower moisture content than mealworms and is marginally higher in protein and metabolizable energy (Finke ,2002).

•Amino-acids : beef is higher in glutamic acid, lysine and methionine and lower in isoleucine, leucine, valine, tyrosine and alanine, compared with mealworms (Finke ,2002).

Fatty acids: beef contains more palmitoleic, palmitic and stearic acid than mealworms, but far higher values in essential linoleic acids were present in mealworms (Finke ,2002).

Howard and Stanley-Samuelson (1990) analysed the phospholipid fatty acid composition of the adult *T. molitor* and found that over 80 percent of these fatty acids consisted of palmitic, stearic, oleic and linoleic acids .

Finke (2002) found the same fatty acids in high amounts in *T. molitor* larvae. Polyunsaturated fatty acids are mostly found as phospholipids.

Minerals: mealworms contain comparable values of copper, sodium, potassium, iron, zinc and selenium (Finke ,2002).

Vitamins. Mealworms have generally higher vitamin content than beef, with the exception of vitamin B12 (Finke, 2002).

The extent to which generalizations can be made about the nutrient content of *T. molitor*, for example, need a dietary carbohydrate concentration of at least 40 percent to develop, and optimal growth is reached when the insect is grown on diets containing 70 percent carbohydrates (Behmer,2006).

Additionally, larvae grow and develop faster when a water source is available than when reared on dry food only, larvae reared in the presence of moisture are, moreover, heavier; this difference in weight is due not to higher water content but to a higher fat content because although insects can be fed on low-value organic waste streams it will affect their nutritional values (FAO, 2013)

**Table 5: Average approximate analysis of selected *Tenebrio molitor* and beef as a percentage of dry matter except for moisture content.**

	<i>T. molitor</i>	Beef
Moisture (% of fresh weight)	61.9	52.3
Protein	49.1	55.0
Fat	35.2	41.0
Metabolizable energy (kcal/kg)	2 056	2 820

Source: Finke, (2002).

## 2.5 Insect farming

Most edible insects are harvested in the wild, but a few insect species have been domesticated because of their commercially valuable products (FAO,2013).Silkworms and bees are the best-known examples, sericulture – the practice of rearing silkworms for the production of raw silk – has its origins in China and dates back 5 000 years, the domesticated form has increased cocoon size, growth rate and efficiency of digestion, and is accustomed to living in crowded conditions ,the adult can no longer fly and the species is completely dependent on humans for survival (FAO,2013).

According to FAO(2013) insect cultivation can be carried out in urban, peri-urban and rural areas and is an efficient use of space, minilivestock enterprises are advantageous because they :

- Require minimal space.
- Do not compete directly with food for human consumption.
- Have a demand which outstrips their suppl.
- Have high reproductive rates.
- Create cash inflow in a short period.
- Have high to very high financial returns in many cases.
- They are nutritional and a part of human nutrition.
- Convert feed to protein efficiently.
- Relatively easy to manage.
- Easily transportable.
- Often easy to raise and do not require in-depth training .

In temperate regions there are companies that produce large numbers of insects as pet food and fish bait ,the species most used are crickets (*Gryllodius sigillatus*, *Gryllus bimaculatus* and *Acheta domesticus*), mealworms (*Zophobas morio*, *Alphitobius diaperinus* and *Tenebrio molitor*), locusts (*Locusta migratoria*), sun beetles (*Pachnoda marginata peregrine*), wax moths (*Galleria mellonella*), cockroaches (*Blaptica dubia*) and maggots of the housefly (*Musca domestica*) (fAO,2013) .

Insects are also produced for educational and recreational purposes , the potential uses of insects are vast , recently, the use of insects for the bioconversion of manure and waste has been explored (fAO,2013) .

## **2.6 Preparation and processing of edible insects**

Insects are often consumed whole, but can also be peeled and processed, western societies might be reluctant to consume whole insects and therefore insect-based flour, granules and pastes that are included in other products can offer alternatives. It is also possible to extract protein, fats, chitin, minerals and vitamins from insects, however, these procedures can be costly and development is needed to

make them applicable for industrial use .Products such as protein-enriched porridge, taco bread, muffins, protein bars and snacks have been developed , preservation of insects and insect products is an area that needs to be further developed (Jansson and Berggren, 2015).

### **2.6.1.Hazards**

Insects like other common foods, may cause allergic symptoms, even after the 1st exposure, moreover, involuntary ingestion is quite frequent considering that insects (or parts of them) are common food contaminants (Belluco *et al.*, 2013) .It has also been demonstrated that some allergens are common to different kinds of food leading to cross-reactivity phenomena , this is the case, for example, of insects and crustaceans for these reasons, insect consumption should take into account the real possibility of adverse reactions and appropriate indications in food labeling should be require (Belluco *et al.*, 2013).

From a microbiological point of view it has been widely demonstrated that insects can harbor different kinds of food pathogen bacteria , nevertheless, research has been generally limited to farm pests like darkling beetle and flies and designed to evaluate their potential role in livestock contamination (Belluco *et al.*, 2013) .

However, since microbiological concerns are well known and widely diffused in animal farming and in the derived food chain, they cannot be considered as hazards sufficient to justify insect limitation or exclusion from the food market (Belluco *et al.*, 2013).

The possibility for insects to harbor parasites has also been described, but in the light of common animal husbandry practices, this risk can be reduced, since parasites are strictly connected to environmental features that maintain the parasitic life cycle (Belluco *et al.* ,2013).

On the basis of current knowledge, to reduce parasitic and other biological risks that could be connected with insect consumption by humans simple hygienic

measures (as appropriate cooking and/or freezing) should be applied during food processing, as suggested for poultry, pork, and fish (Belluco *et al.* ,2013).

Following a few preventive measures can reduce chemical risks connected with insect consumption, in order to avoid the toxic effects of insects due to the synthesis of poisons, an accurate selection of species should be envisaged before farming and appropriate regulations have to be settled to ban species recognized to be dangerous for humans on a case by case basis (Belluco *et al.* ,2013).

To counteract chemical bioaccumulation, a controlled feed program needs to be considered, focusing particularly on feed composition and feed contamination by chemicals. “Food Defect Action Levels” is the official U.S. FDA regulation concerning insect parts in food products and pertains to “Levels of natural or unavoidable defects in foods that present no health hazards for humans” (Belluco *et al.*, 2013).

It established the maximum permitted level of insects or parts thereof in food by considering them from an aesthetic (offensive to the senses) point of view rather than as a biological hazard (Belluco *et al.*, 2013).

Likewise, the EU classifies the presence of visible insects larvae in food as “foreign bodies,” as reported in the RASFF (Rapid Alert System for Food and Feed) database, otherwise only the presence of viable larvae is classified as microbiological hazard , evidently if insects were considered as food, the foreign body classification would consequently be lost (Belluco *et al.* , 2013).

### **2.6.2. Shelf life**

shelf life is an important consideration for any food product , much research is needed for this aspect of insect-based foods as very little information on insect shelf life is currently available .Nonetheless, some known features of insects may suggest that insect-based food ingredients may have an advantage of longer shelf life than similar non insect alternatives, particularly for dry products or pastes with high levels of insect content (Shockle and Dossey, 2014) .

for example, a number of insects have been shown to contain antimicrobial substances such as peptides, fatty acids and other secondary metabolites which may lend themselves to extending the shelf life of insect-containing foods , additionally, the chitin from insects is known to have antimicrobial properties (Shockle and Dossey, 2014) .

Thus, even though in many cases the texture of insect-based foods is improved by removing chitin), in other food products there may be advantages in leaving the chitin , in those cases, the texture issues with chitin might be alleviated by grinding the insects into a fine powder, while maintaining the fiber and antimicrobial benefits of chitin (Shockle and Dossey, 2014) .

### **2.6.3. Preservation and marketing**

Because many insects are only seasonally available, they are frequently conserved for later consumption, this is often done by drying insects in the sun, over ashes or in the oven , preservation with salt after boiling is also common ,Some insects are not prepared at all and are eaten alive ( Jansson and Berggren, 2015).

In most parts of Africa a small quantity of termites is eaten alive as a relish during collection in South Africa, the heteropteran insect *N. delegorguei* is also eaten alive , in discussing the preparation, preservation and marketing of insects, the insect groups will be treated in order of importance ( Jansson and Berggren, 2015).

### **2.6.4. Legal obstacles**

Insects are not yet fully approved as food within the EU, since risk assessments are lacking , The European Food Safety Authority (EFSA) is working on this and will deliver a report.However, the Dutch and Belgian food authorities have already published some risk assessments (EFSA, 2014) , it is likely that insects will be approved for food use one species at a time and it is possible that some species will be accepted during 2016 (Livsmedelsverket, 2015).

## 2.7. Locust

Locusts are members of the grasshopper family Acrididae, which includes most of the short-horned grasshoppers.

Locusts differ from grasshoppers because they have the ability to change their behavior and physiology, in particular their color and shape (morphology) in response to changes in density (Symmons and Cressman , 2001).

Class	Insecta	
Order	Orthoptera	Grasshoppers (about 20 000 species worldwide)
Suborder	Caelifera	Short-horned grasshoppers
Super family	Acridoidea	(about 10 000 species worldwide)
Family	Acrididae	Grasshoppers and locusts
Subfamily	Cyrtacanthacridina	
Genus	Schistocerca	
Species	Gregaria	

Adult locusts can form swarms which may contain thousands of millions of individuals and which behave as a unit , the non-flying nymphal or hopper stage can form bands, a band is a cohesive mass of hoppers that persists and moves as a unit. In general, most grasshoppers do not form bands or true swarms , however, the distinction between locusts and grasshoppers is not clear-cut since some of the latter do form bands (e.g. *Melanoplus*, *Acridoderes*, *Hieroglyphus sp.*) or small loose swarms (e.g. *Oedaleus senegalensis*) , locusts such as the Tree Locust have never been known to form bands (Symmons and Cressman , 2001) .

## 2.8. Describing population density

By adopting standard descriptions for locust densities landholders can accurately describe the extent of their locust infestation, this information is important when coordinating control operations (DAF, 2016).

## 2.9. Biology and behavior

Some kinds of Locusts have the ability to change their behavior, physiology, color and shape in response to a change in locust numbers , at low numbers, locusts behave as individuals (solitarious phase); at high numbers, they behave as a single mass (gregarious phase) , precise thresholds at which these changes occur are not established. Three processes are involved in phase transformation: concentration, multiplication and gregarization (Symmons and Cressman , 2001).

## 2.10. The life cycle

The Desert Locust, like all other locusts and grasshoppers, passes through three

**Table 6: Number of locust per m<sup>2</sup>**

Adults		Nymphs	
<b>Concentration</b>	0,5-3	Present	1-5
<b>low density swarm</b>	4-10	numerous	6-30
<b>Medium density swarm</b>	11-50	Sub -band	31-80
<b>High density swarm</b>	<50	Band	<80

Source: DAF, (2016).

stages: egg, nymph (hopper) and adult. Eggs are laid by female , they hatch into wingless larvae or nymphs called hoppers.Hoppers shed their skins five or six times, each time growing in size , this process is called moulting and the stage

between moults is referred to as an instar, the number of instars varies between species (from 5–9) , as does the time taken to reach maturity (DAF ,2016).

The final moult from the wingless fifth (or sixth) instar hopper to the winged adult is called fledging , the new adult, known as a fledgling, has soft wings that must dry and harden before it can fly, adults do not moult and therefore do not grow in size but gradually increase in weight , adults that can fly are initially sexually immature, but eventually become sexually mature and can copulate and lay eggs (DAF ,2016).

### **2.11. Locust as food**

Even though grasshoppers produce only one generation per year, they constitute such an enormous biomass that people all over the world dry the insects and then sell and consume them .The swarming behaviour makes locusts relatively easy to harvest for food (Heuzé and Tran, 2016).

Most of the grasshopper species in the world are edible (Ramos-Elorduy *et al.*, 2012) ,in Africa, the desert locust (*Schistocerca gregaria*), the migratory locust (*Locusta migratoria* ), the red locust (*Nomadacris septemfasciata*) and the brown locust (*Locustana pardalina*) are commonly eaten. In Japan, China and Korea, rice field grasshoppers are utilized as food (Heuzé and Tran, 2016).

Ramos-Elorduy and other they study the nutritive value of 25 edible Orthoptera in Mexico showing , protein content ranges from 43.93% to 77.13% (mix of Edible Acrididade of Puebla) ,fat percentage goes from 4.22% to 34.21% (Ramos-Elorduy *et al.*, 2012).

In Mexico, chapulines, which are grasshoppers of the *Sphenarium* genus, and notably *Sphenarium purpurascens*, a pest of alfalfa, are popular edible insects (Heuzé and Tran, 2016).

Richest species in ashes were *Arphia fallax* S., *Sphenarium histrio* G. and *Sphenarium purpurascens* Ch. with 16.5%,energy contribution varies from

14.05 kJ to 21.88 kJ .Their amino acids profile was compared with the WHO/FAO/UNU Pattern (1985) , the total quantity of essential amino acids that all insects species provides was superior to those signaled in the pattern , the highest quantity (53.60 g) was for *Sphenarium histrio* G. , chemical score goes from 50% to 88% (Ramos-Elorduy *et al.*, 2012).

In vitamins, the highest value in Thiamine and Riboflavine was for *Sphenarium magnum* M., in Niacine for *Sphenarium borrei* B., in vitamin C and for vitamin D *Acheta domestica* L., and in Vitamin A for *Periplaneta americana* L. ( Ramos-Elorduy *et al.* , 2012).

Minerals of all species were very rich in magnesium.

In the Sahelian region the sale of harvested and marketed grasshoppers and locusts may yield more revenue for farmers than millet ,this is one of the reasons that farmers prefer not to treat their crops with pesticides (Van Huis, 2003).

All the edible orthopterans results were compared with those of the most conventional Mexican foods used to obtain proteins, the quantity and quality of the nutrients that these edible orthopterans allows, provides a significant contribution to the nutrition of the peasants who eat them (Ramos-Elorduy *et al.*, 2012).

The spiny legs and wings of hoppers are removed, some tribes also remove the head together with the intestines, and sometimes only the thorax is eaten (Sudan) (Van Huis, 2003).

Both the adult and hopper stages of all locust species are consumed when and wherever they occur, many univoltine adult grasshopper species are also eaten, in particular in the Sahel. The larger species, mainly .the females, are preferred ,at the end of the rainy season they contain a lot of fat and the females hold many eggs (Ramos-Elorduy *et al.*, 2012).

The insects are cooked, fried or roasted the San women in the central Kalahari roast them in hot ash and sand after picking off the heads and removing the

internal organs, which are considered to be excrement ,flying locusts and grasshoppers (and to a greater extent hoppers) are sun-dried before storage, pounded in a mortar to powder, and eaten with porridge (Van Huis, 2003).

The *tettigoniid* *R. differens* is considered a delicacy in the whole of central, eastern and southern Africa ,in Uganda, the tettigoniid is called Ônsenene which is in Ganda the word for the month of November during which the grasshopper appears in large number, butchery owners and fishmongers are affected because few customers go then for meat or fish, before frying them, the antenna, legs and wings are removed , the Naro in DÕkar make grasshopper powder by pounding them in a mortar, to mix it with maize flour in porridge (Van Huis, 2003).

Riley conducted extensive studies and mounted a strong advocacy effort on the food potential of the Rocky Mountain locust he said " Whenever the occasion presented I partook of locusts prepared in different ways, and one day, ate of no other kind of food, and must have consumed, in one form and another, the substance of several thousand half-grown locusts, commencing the experiments with some misgivings, and fully expecting to have to overcome disagreeable flavor, i was soon most agreeably surprised to find that the insects were quite palatable, in whatever way prepared (Adam,1967) .

Broth made by boiling the unfledged Carotene for two hours in the proper quantity of water, and seasoned with nothing in the world but pepper and salt, is quite palatable, and can scarcely be distinguished from beef broth, though it has a slight flavor peculiar to it and not easily described , the addition of a little butter improves it, and the flavor can, of course, be modified with mint, sage, and other spices ad labium ,fried or roasted in nothing but their own oil, with the addition of a little salt, and they are by no means unpleasant eating, and have quite a nutty flavor in fact, it is a flavor, like most peculiar and not unpleasant flavors, that one can soon

learn to get fond of prepared in this manner, ground and compressed (Adam,1967).

Prof. H.H. Straight, at the time connected with the Warrensburg, (Mo.) Normal School, who made some experiments for (Adam,1967) in this line, wrote: 'We boiled them rather slowly for three or four hours, seasoned the fluid with a little butter, salt and pepper, and it made an excellent soup, actually; would like to have it even in prosperous times (Adam,1967).

## **2.12. Harvesting and farming**

Desert locust (*Schistocerca gregaria*) are usually collected in the wild, preferably at night (using artificial light) or in the morning when the temperature is cooler and the insects are less active and easier to catch (Heuzé and Tran, 2016).

The San women in the Central Kalahari collect the grasshoppers by hand in the morning and the evening from trees and huts, To collect locust and grasshoppers, Gbaya women in the Central African Republic, very early in the morning use brooms made from leaves or branches to sweep the savanna vegetation which has been cut the day before, in order to catch the jumping insects, in Madagascar there is a proverb "how can you capture ovipositing grasshoppers and have a late morning at the same time?" it indicates that you can only catch the very much appreciated gravid female grasshoppers very early in the morning, in Tanzania, in addition to collecting the edible grasshopper *deferens* early in the morning, people lit fires so the smoke keeps down the flyers (Heuzé and Tran, 2016).

The Gbaya in the Central African Republic use a stick from *Lantana rhodesianus* or grass stems of *Andropogon gayanus* with glue at the end, to collect grasshoppers (Van Huis, 2003).

Due to the demand, commercial farming of locusts, grasshopper for the food and feed market is developing in South East Asia (Heuzé and Tran, 2016)

### **2.13. Processes**

Locusts and other Orthoptera used for livestock feeding are fed live to free-range chickens, pets and zoo animals, but dried and ground for broilers and fish. Sometimes they are boiled before drying (Heuzé and Tran, 2016).

### **2.14. Environmental impact**

The harvesting of locusts and other pest grasshoppers for food and feed is a means for their biological control and may help to reduce the application of chemical pesticides and, thereby, environmental pollution. In Thailand, the outbreak of patanga locust (*Patanga succincta*) in maize in the late 1970s led to a campaign to promote the eating of this locust, which is now farmed for food purposes (Heuzé and Tran, 2016).

Study revealed that the locust (*Locusta migratoria L.*) produces no methane, 2.37g of carbon dioxide equivalents, and 5.4 mg of ammonia per kg body mass every day, these levels are very low in comparison with beef which produces up to 0.28 g of methane, 7.08 g of carbon dioxide equivalents, and 170.00 mg of ammonia (Oonincx., 2010).

In the USA, methane emissions associated with enteric fermentation and manure management constitute 31% of total methane emissions, which is the largest contributor of these emissions, ranking even above the petroleum industry (EPA, 2015).

Studies indicate that the highest levels of carbon dioxide equivalents are being released from beef production, followed by pork and chicken (Fiala, 2008).

### **2.15. Future demand of protein**

The world needs more protein to feed a growing and underfed population, current animal production systems will not meet this demand in a sustainable way. The world demand for animal-derived protein is expected to double by 2050 (FAO, 2013), driven by: increasing population (9 billion by 2050), emerging economies, increasing urbanization, recognition of protein's

role in a healthy diet , Increased need for protein in the elderly (Boland, 2013 ).

Three simultaneous changes will need to be made to meet future animal-derived protein demand, namely: shifting protein sources up the supply chain ,use of plant-based substitutes or extenders for animal derived protein foods ,use of novel sources for both animal and human nutrition, one of novel protein sources is Insect protein (Boland, 2013 ).

Encouraging the direct use of insects as food in societies should not be the major objective at this stage changing attitudes to eating insects is paramount to success the main challenge is to change attitudes to eating insects (Yen, 2009).

Rather than encouraging societies to eat insects directly, the strategy should be promoting:

(i) insects as food supplements.

(ii) insects as part of livestock production systems to reduce adverse environmental effects of animal protein production .

Westernized societies have the resources to develop small (on-farm) to large (factory) controlled insect production systems for human use (food supplements) or livestock food (Yen, 2009).

## **CHAPTER THREE**

### **MATERIALS AND METHODS**

#### **3.1. Materials**

##### **3.1.1. Locust sampling area and sample collection**

Samples of locust (*Schistocerca gregaria*) were purchased from South Kordofan, Al Gadarf and some others were collected randomly from Northern State using net and some were handpicked .

##### **3.1.2. Other materials**

Beef, chicken, bean, egg and wheat flour were brought from the local market as well.

##### **3.1.3. Preparation of locust sample**

The sample from different locations was sun dried, mixed and ground.

##### **3.1.4. Preparation**

Beef and chicken from different locations were mixed and minced each type separately .Beans from different locations were mixed and ground. Wheat flour and egg from different locations were mixed separately.

#### **3.2. Methods**

##### **3.2.1. Proximate chemical analysis**

##### **3.2.1.1. Determination of moisture content**

This measures the water content of sample, 2 g of each prepared samples were weighed into a pre-heated, cooled and weighed silica dish, it was dried in the oven for 24 h at a regulated temperature of 105°C to a constant weight. The dish and the content was allowed to cool in a desiccators before weighing. The moisture was determined as percentage moisture given by(AOAC, 1990):

Moisture % =

$$\frac{\text{Wt before drying (g)} - \text{Wt after drying (g)} \times 100}{\text{Wt sample taken (g)}}$$

### 3.2.1.2. Determination of ash content

This measures the mineral content of samples, crucibles were thoroughly beheld, cleaned and placed in a hot air-oven for 2 h and allowed to cool to room temperature in a desiccators, the empty crucibles were transferred to the muffle furnace to burn off all organic matter and also, to stabilize the weight of the crucible (AOAC,1990). Five g of samples were accurately weighed into the labeled crucibles, placed in the muffle furnace and ashed at 600°C, for 5 h, at the end of the ashing period, the ashed samples were removed into a desiccator to cool to room temperature and were reweighed (AOAC, 1990).

Ash %=

$$\frac{\text{Wt of crucible and ash (g)} - \text{Wt of crucible (g)}}{\text{Wt of sample (g)}} \times 100$$

### 3.2.1.3. Determination of crude protein

Sample Preparation : Solid foods are ground; samples for analysis should be homogeneous.

Digestion:

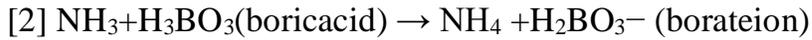
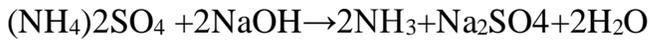
Two g of sample (accurately weighed) was placed in a Kjeldahl flask, 5ml of sulfuric acid and 1 g catalyst were added (copper sulfate, potassium sulfate). Then digested until get complete breakdown of all organic matter, nonvolatile ammonium sulfate is formed from the reaction of nitrogen and sulfuric acid.

Protein + sulfuric acid  $\xrightarrow{\text{Heat, catalyst}}$   $(\text{NH}_4)_2\text{SO}_4$

[1] During digestion, protein nitrogen is liberated to form ammonium ions; sulfuric acid oxidizes organic matter and combines with ammonium formed; carbon and hydrogen elements are converted to carbon dioxide and water.

Neutralization and Distillation

The digest is diluted with water, alkali-containing sodium hydroxide is added to neutralize the sulfuric acid, the ammonia formed is distilled into a boric acid solution containing the indicators .



[3] Titration Borate anion (proportional to the amount of nitrogen) is titrated with standardized HCl.  $\text{H}_2\text{BO}_3^- + \text{H}^+ \rightarrow \text{H}_3\text{BO}_3$

[4] Moles of HCl = moles of  $\text{NH}_3$  = moles of nitrogen sample

[5] A reagent blank runned to subtract reagent nitrogen from the sample nitrogen.

$$\% \text{N} = \text{NHCl} \times \text{Corrected acid volume} \times 14 \text{gN mol} \times 100$$

Where: NHCl = normality of HCl, in mol/1000ml

$$\text{Corrected acid vol.} = \frac{(\text{ml std. acid for sample}) - (\text{ml std. acid for blank})}{14}$$

14 = atomic weight of nitrogen

A factor is used to convert percent N to percent crude protein. Most proteins contain 16% N, so the conversion factor is 6.25 ( $100/16 = 6.25$ ).

$$\% \text{N} / 0.16 = \% \text{protein}$$

or [7]  $\% \text{N} \times 6.25 = \% \text{protein}$  (Nielsen, 2010).

#### **3.2.1.4. Determination of fat**

This measures the lipid content of sample, this was done mainly by the method of AOAC (1990), 5 g of sample was weighed into a thimble and Soxhlet apparatus was set, the lipid contained in the dry sample was exhaustively extracted using petroleum ether for 3 h, the extractant (petroleum ether) was distilled off and the flask was re-weighed. The percentage lipid was calculated thus.

$$\text{Lipid\%} = \frac{\text{Wt of flask and lipid (g)} - \text{Wt of flask (g)}}{\text{Wt of sample (g)}} \times 100$$

### **3.2.1.5. Determination of fiber**

The contents quantitatively put in pre-weighed crucible and re-weighed again, the crucible was ignited at 550°C for 2 h, cooled in desiccators and weighed (AOAC, 1990).

Crude fiber % =  $\frac{\text{Loss in Wt on ignition (g)}}{\text{Wt of sample (g)}}$

Wt of sample (g)

### **3.2.1.6 Determination of available carbohydrates**

This measures the carbohydrate content and in most cases includes the fiber content of the sample, this was conveniently done by the difference method that is:

Available CHO =  $100 - (\% \text{ lipid} + \% \text{ ash} + \% \text{ moisture} + \% \text{ protein} + \% \text{ Fiber})$ .

### **3.2.2. Determination of mineral content**

One g of the samples were weighed in a muffle furnace at 4500°C in porcelain dish used for ashing the ash was dissolved in 5 ml of 20% hydrochloric acid and completed the volume to 50 with distilled water. The elemental analysis of the samples were, performed using Atomic Absorption Spectrometer (Shimadzu AA-680, Shimadzu, Japan) for Ca, Mg and Fe, while Flame photometer 410 (Sherwood Scientific Ltd) was used to determine the K and Na content (Tandon, 1993).

### **3.2.3. Determination of energy value**

The caloric value (cal/g) was calculated by multiplying the mean of crude protein and total carbohydrate by factor 4 of each and that of crude fat multiplied by 9 and summing up the total (Onyeike *et al.*, 1995)

### **3.2.4. Statistical analysis**

Duplicate determinations were carried out on each sample (N = 2) and results are quoted as mean + standard deviation (SD).

The data were assessed by variance analysis (ANOVA) at 0.05 confidence limit and two sample T test using Minitab, version 14.

## **CHAPTER FOUR**

## 4. RESULTS AND DISCUSSION

### 4.1. Proximate chemical composition and energy value of locust (*Schistocerca gregaria*).

The proximate chemical composition and energy value of locust (*Schistocerca gregaria*) shown in table 7 as percent % revealed that:

#### 4.1.1. Moisture content

Moisture content represent only  $6.44 \pm 0.75\%$  on wet weight .On base of wet weight similar result was obtained by Adeyemo *et al.* (2008) was 6.0% ,different to that of Mohamed (2015) who reported result 3.81%. Studies have indicated that there is factor such as sex, stage of life and environmental factors (temperature, day length, humidity, light intensity, etc) , can influence the chemical composition of insects (Finke *et al.*, 2014).

The results represent quite low amount of moisture which may be advantageous in view of the samples shelf-life ,the moisture content of the entire insects are generally low , this indicates that they can all be preserved for a reasonable period of time without the risk of microbial deterioration and spoilage .The long shelf-life promised here is an added advantage over other sources of protein like beef (Jonathan,2012).

#### 4.1.2. Protein content

protein content of locust (*Schistocerca gregaria*) is about  $50.55 \pm 0.24\%$  based of wet weight , on dry weight it was  $53.803 \pm 0.50\%$ .The obtained result based on wet weight it's similar of result reported by Mohamed (2015) which it was 50.42% while Adeyemo *et al.* (2008) reported 52.30%. All result agreed on that locust (*Schistocerca gregaria*) has exceptional amountof protein,protein content of insects vary between and within insect orders, also varies strongly by species , feed and metamorphosis stage (FAO,2013).

**Table 7: Proximate chemical composition and energy value of locust (*Schistocerca gregaria*).**

<b>Proximate chemical composition%</b>	<b>Locust</b>	
	<b>On wet basis</b>	<b>On dry basis</b>
<b>Moisture</b>	6.44± 0.75	-
<b>Protein</b>	50.55± 0.24	53.803± 0.50
<b>Fat</b>	27.95± 1.07	29.815± 0.85
<b>Available carbohydrates</b>	0.017± 0.00	0.018± 0.01
<b>Fiber</b>	10.23± 0.19	10.968± 0.25
<b>Ash</b>	4.74± 0.27	5.053± 0.36
<b>Caloric value : K.cal \ 100 g DM</b>	494.80 ±9.82	527.49±6.4

**Values are means ±SD.**

**SD = Standard deviation.**

#### **4.1.3. Fat content**

The fat content represented average  $27.95 \pm 1.068$  % based on wet weight ,the dry weight result was  $29.815 \pm 0.85$ %. The value of  $29.815 \pm 0.85$ % based on dry weight is higher than that reported by Mohamed (2015) who stated 19.62% .The fatty acid composition of insects appears to be influenced by the plants on which they feed (FAO,2013).

#### **4.1.4. Available carbohydrates content**

The carbohydrates formed average for wet weight and dry weight  $0.017 \pm 0.00$  % and  $0.018 \pm 0.01$  % ,respectively .The value of  $0.017 \pm 0.00424$ % based on wet weight is lower than 4.78% the value reported by Mohamed (2015) .In both results it low value which make the locust (*Schistocerca gregaria*) not suitable source for carbohydrate .

#### **4.1.5. Fiber content**

Fiber content in locust (*Schistocerca gregaria*) based on wet weight was  $10.23 \pm 0.191$ % and on dry weight was  $10.968 \pm 0.25$ %. Mohamed (2015) reported higher value 15.65% based on wet weight . These results are significantly high and could be attributed to little amount of chitin found normally in insects (Oduoret *al*, 2008).

#### **4.1.6. Ash content**

The result of ash content based on wet weight was  $4.74 \pm 0.27$ % and on dry weight was  $5.053 \pm 0.36$ %. The ash value  $4.74 \pm 0.27$ % obtained here based on wet weight is slightly lower than the value 6.24% reported by Mohamed (2015) for locust (*Schistocerca gregaria*) , although the value 10.0% reported by Adeyemo *et al*.(2008) was higher.

The ash content of a sample is a reflection of the minerals it contains ,these insects were therefore found to be rich in minerals .The level of minerals present in edible

insects indicates that insects are good sources of minerals for the human body ( Lokeshwari and Debaraj, 2014).

#### **4.1.7. The energy value**

The energy value of locust based on wet weight was  $494.80 \pm 9.82$  it's lower than result based on dry weight was  $527.49 \pm 6.4$ .

### **4.2 Proximate chemical composition and energy value of beef**

The proximate chemical composition and energy value of beef in table 8 showed that :

#### **4.2.1. Moisture content**

The moisture content measured of beef based on its wet weight was  $63.750 \pm 0.212\%$ . The wet weight result  $63.750 \pm 0.212\%$  is lower than the result  $70.47\%$  obtained by Alaminet *al.* (2016) and the result  $73.1\%$  reported by Williams (2007).

#### **4.2.2. Protein content**

The results of protein obtained for beef was  $52.69 \pm 0.35\%$  base on dry weight ,the wet weight was  $19.100 \pm 0.849\%$ , which slightly lower than result  $20.50\%$  obtained by Alaminet *al.* ( 2016) and the result  $23.2\%$  of Williams(2007). Both result is lower than the result reported by FAO (2007) which was  $22.3\%$ .

#### **4.2.3. Fat content**

The fat content of beef was found to be  $36.273 \pm 0.763\%$  based on dry weight , while on wet weight base was  $13.150 \pm 0.354\%$ .

The wet weight  $13.150 \pm 0.354\%$  is higher than the result of Williams (2007) which was  $10.8\%$ . The dry weight result ( $36.273 \pm 0.763\%$ ) is less than Finke (2002) which was  $41\%$ .

#### **4.2.4. The available carbohydrates content**

The carbohydrates content of beef was  $3.544 \pm 0.0375\%$  based on dry weight , the wet weight was  $1.2850 \pm 0.0212\%$ .

**Table 8 : Proximate chemical composition and energy value of beef**

<b>Proximate chemical composition %</b>	<b>Beef</b>	
	<b>On wet basis</b>	<b>On dry basis</b>
<b>Moisture</b>	63.750 ± 0.212	-
<b>Protein</b>	19.100 ± 0.849	52.69± 0.35
<b>Fat</b>	13.150 ± 0.354	36.273± 0.763
<b>Available carbohydrate</b>	1.2850 ± 0.0212	3.544± 0.0375
<b>Fiber</b>	1.270 ± 0.382	3.51± 1.07
<b>Ash</b>	1.250 ± 0.354	3.455± 0.997
<b>Caloric value : K.cal \ 100 g DM</b>	204.97 ±5.13	565.40±10.84

**Values are means ±SD**

**SD = Standard deviation**

#### **4.2.5. Fiber content**

The amount of fiber content of beef was  $3.51 \pm 1.0$  % based on dry weight , the wet weight was  $1.270 \pm 0.382$ %.

#### **4.2.6. Ash content**

The ash content of sample of beef based on dry weight was  $3.455 \pm 0.997$ % and based on wet weight was  $1.250 \pm 0.354$  % .The wet weight value is almost the same as 1.2% reported by FAO (2007) and higher than 0.92% reported by 0.92% Alamin *et al.*(2016) .

#### **4.2.7. The energy value**

The energy value of beef calculated on dry weight was  $565.40 \pm 10.84$  cal \ 100 g , and on wet weight was  $204.97 \pm 5.13$  cal \ 100 g

### **4.3. Comparison between proximate chemical composition and energy values of locust (*Schistocerca gregaria*) and beef based on dry weight.**

The result of the proximate composition of both locust(*Schistocerca gregaria*) and beef are shown in Table 9.

#### **4.3.1. Protein content**

Referring to the results of protein in table 9 stated that the locust and beef were fairly rich in protein.

Locust (*Schistocerca gregaria*) is marginally higher in protein which is  $53.803 \pm 0.499$ % and the protein content of beef was  $52.69 \pm 0.35$  % there is no significant differences between the two means.

The protein content exhibited by the insects was significantly higher than in conventional animal meats, and therefore insects may offer an affordable source of protein to counteract protein malnutrition ( Lokeshwari and Debaraj , 2014).

The requirement for dietary protein consists of two components; (a) a requirement for the nutritionally essential amino acids, (b) the need to meet the requirement for non-specific nitrogen in order to supply the nitrogen necessary for synthesis of the nutritionally not essential amino acids and other

**Table 9 :Comparison between proximate chemical composition and energy value of locust (*Schistocerca gregaria*) and beef based on dry weight.**

<b>Proximate chemical composition</b>	<b>locust Mean± SD (%)</b>	<b>Beef Mean± SD (%)</b>
Protein	53.80 <sup>a</sup> ± 0.50	52.69 <sup>a</sup> ± 0.4
Fat	29.815 <sup>b</sup> ± 0.83	36.273 <sup>a</sup> ± 0.8
Available carbohydrates	0.018 <sup>b</sup> ± 0.004	3.544 <sup>a</sup> ± 0.0
Fiber	10.968 <sup>a</sup> ± 0.25	3.51 <sup>b</sup> ± 1.1
Ash	5.053 <sup>a</sup> ± 0.36	3.455 <sup>a</sup> ± 0.9
Energy value : (cal\100gram)	527.49 <sup>a</sup> ±6.4	565.40 <sup>a</sup> ±10.9

**SD = Standard deviation**

**\*Means that do not share letters are significantly different.**

physiologically important nitrogen containing compounds (nucleic acids, creatine, porphyrins) (Gerber,2007).

#### **4.3.2. The fat content**

The fat content of beef was  $36.273 \pm 0.763\%$  higher than that of locust (*Schistocerca gregaria*)  $29.815 \pm 0.827\%$  (there is significant differences) .

Fat is source of energy and supplies essential nutrients and helps to absorb fat-soluble vitamins (A, D, E and K), fat also provides palatability and flavor to food (Gerber,2007) .

#### **4.3.3.The available carbohydrates content**

The amount of carbohydrate resulted for locust was  $0.018 \pm 0.00424\%$  lower than the beef which was  $3.544 \pm 0.0375\%$  and there is significant difference between the means.

Insects generally not good source of carbohydrate, human adult need about 400 – 500g carbohydrate intake as starch (Jonathan,2012) .

#### **4.3.4.The fiber content**

The locust (*Schistocercagregaria*) had higher value of fiber  $10.968 \pm 0.252\%$  than beef  $3.51 \pm 1.07\%$  and there is significant difference between the means .

Fiber in diets is believed to aid weight control, fat reduction and maintain the proper peristaltic movement of the intestinal tract to prevent constipation ,the relatively high fiber level observed may be attributed to low chitin content generally observed in insects ( Oduoret *al.*,2008).

#### **4.3.5.The ash content**

The ash content of locust was  $5.053 \pm 0.364\%$  and the beef ash content was  $3.455 \pm 0.997\%$  there is not significant difference between thr two .

Ash content accurately reflects the mineral content but does not differentiate between minerals ( Pearsonand Tauber,2012) the result indicate both have good amount of minerals.

#### **4.3.6. The energy value**

The energy value of beef was  $565.40 \pm 10.84$  cal/100g is slightly higher than locust (*Schistocerca gregaria*) which was  $565.40 \pm 10.84$  cal/100g .

None of the insects when taken in isolation as diet can meet the recommended daily allowance of 2500 – 3500 kcal , these insects need to be taken alongside with other food items or taken as snacks, tip-bits and delicacy , however, insects can contribute greatly to the caloric content of food (Jonathan , 2012 ) .

#### **4.4. Comparison between protein content of locust (*Schistocerca gregaria*) and some conventional protein sources**

Table 10 displays quantities of protein that some conventional protein sources possess in comparison with locust (*Schistocerca gregaria*) . There was no significant difference between the locust (*Schistocerca gregaria*) and the beef  $53.8^a \pm 0.049\%$ ,  $52.69^a \pm 2.03\%$  , respectively . Compared with other samples they have superior value of protein above the other sources of protein (chicken  $44.50^b \pm 1.70$ , egg  $44.30^b \pm 2.69$ , bean  $23.1^c \pm 0.56$  ,wheat flour  $16.35^d \pm 1.48$ ) . The result indicates that locust (*Schistocerca gregaria*) can be promising source of protein.

#### **4.5. Minerals content of locust (*Schistocerca gregaria*).**

Table 11 represents some of the essential minerals content of locust

##### **4.5.1. Sodium content**

From the result of the table the concentration of Sodium was the most prominent in the locust (*Schistocerca gregaria*) sample  $3008.25 \pm 11.67$  mg/kg on dry weight base and the result of wet weight was  $2813.6 \pm 32.0$  mg/kg. The result based on dry weight from this study is higher than  $290.25$  mg/kg that reported by Ajai *et al.* (2013), this high value of sodium can be referred to the local seller usually add salt after drying for consumer liking.

**Table 10: Comparison between protein content of locust (*Schistocerca gregaria*) and some conventional protein sources based on dry weight.**

<b>Food</b>	<b>Mean± SD (%)</b>
Locust	53.8 <sup>a</sup> ± 0.049
Beef	52.69 <sup>a</sup> ± 2.03
Chicken	44.50 <sup>b</sup> ± 1.70
Egg	44.30 <sup>b</sup> ± 2.69
Bean	23.1 <sup>c</sup> ±0.56
Wheat flour	16.35 <sup>d</sup> ± 1.48

**SD = Standard deviation**

**\*Means that do not share letters are significantly different.**

**Table11: Minerals content of locust (*Schistocercagregaria*).**

<b>Minerals</b>	<b>Locust</b>	
	<b>Mean <math>\pm</math> SD(mg/kg)</b>	
	<b>Ondrybasis</b>	<b>Onwetbasis</b>
<b>Sodium</b>	3008.25 $\pm$ 11.7	2813.6 $\pm$ 32.0
<b>Potassium</b>	2651.75 $\pm$ 4.6	2480.4 $\pm$ 23.3
<b>Calcium</b>	275.1 $\pm$ 43.3	257.1 $\pm$ 38.5
<b>Magnesium</b>	370 $\pm$ 21.2	346.0 $\pm$ 17.3
<b>Iron</b>	31.23 $\pm$ 6.1	29.25 $\pm$ 5.9

#### **4.5.2.Potassium content**

The concentration of potassium on dry weight was  $2651.75 \pm 4.60$  mg/kg and on wet weight sample was  $2480.4 \pm 23.3$  mg/kg .The value  $2651.75 \pm 4.60$  mg/kg is higher than that reported by Ajai *et al.* (2013) which is 480,12 mg/kg .

Potassium is important for function of muscles and the nervous system and for water balance in the body.

#### **4.5.3.Calcium content**

The concentration of calcium in the studied sample based on dry weight was  $275.1 \pm 43.3$  mg/kg and base on wet weight was  $257.1 \pm 38.5$  mg/kg.Calcium is important for bones and teeth, shortage of calcium, can lead to weak bones.

The variation between the results of different studies of minerals content could result of ecological factors and variation in species ,the geographical location and their feeding habits (Ajai *et al.*,2013).

Consuming the entire insect is expected to provide higher micronutrient content ( minerals, vitamins) than eating individual insect parts (FAO,2013). Ajai *et al.* (2013) suggest that any consumer intending to source for these essential minerals in order to complement his/her nutrient needs from these insects should concentrate more on locust (*Schistocerca gregaria*).

#### **4.5.4.Magnesium content**

The magnesium concentration in the analyzed sample of locust (*Schistocerca gregaria*) based on dry weight was  $370 \pm 21.2$  mg/kg and based on wet weight was  $346.0 \pm 17.3$  mg/kg .The result based on dry weight was  $370 \pm 21.2$  mg/kg while Ajai *et al.* (2013) reported higher result 1484,17mg/kg .

#### **4.5.5.Iron content**

The iron content in the studied locust based on dry weight was  $31.23 \pm 6.05$  mg/kg and based on wet weight was  $29.25 \pm 5.9$  . The dry weight concentration( $31.23 \pm 6.05$  mg/kg ) is lower than that figured by Ajai *et al.* (2013) of 574,75 mg/kg , both results are much higher than the result reported by

Mohamed (2015) who found 0.554 mg/kg .Iron is important for the blood for hemoglobin to transport oxygen from the lungs to the rest of the body, lack of iron lead to anemia , weakness and shortage of energy.

## CHAPTER FIVE

### 5. CONCLUSIONS AND RECOMMENDATIONS

#### 5.1. Conclusions

- Locust (*Schistocerca gregaria*) could be considered as a good nutritional food source, due to their high nutritional value and widespread use, especially for protein, fiber, fat as well as a potential source of energy. For example 100 g of locust (*Schistocerca gregaria*) can fulfill the meal intake in terms of protein, fat and fiber and the whole daily intake of protein and fiber. Serving just two tablespoons of locust (*Schistocerca gregaria*) as powder (42g) contain 200 cal/g, 21 gram of protein, 12.5 gram of fat, 4.6 gram of fiber, almost nil soluble carbohydrate and 2 gram of minerals.
- locust (*Schistocerca gregaria*) get the better value of protein than some conventional protein source (chicken, wheat flour, egg, bean) that carried out in the study.
- The comparison between locust (*Schistocerca gregaria*) and beef revealed that the proximate composition was close for protein, fat and ash.

#### 5.2. Recommendations

- Introduction of the locust (*Schistocerca gregaria*) in different forms e.g powder in our daily diet because it is rich in protein, fat, fiber. Accordingly locust (*Schistocerca gregaria*) is recommended for consumption by economically weaker sections in developing countries and during starvation time to ease the problem of nutrient/protein malnutrition.
- To use locust (*Schistocerca gregaria*) as an alternative rich protein source for feed of animal.
- Further studies are recommended for detection of pesticides residue, amino acid profile, shelf life and safety.

- The production of locust as alternative protein source can be industrialized .

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## APPEENDICES

Appendix 1: Comparison of the content of 100 gram of locust (*Schistocerca gregaria*) (DM) with the nutrient requirement per one meal on day:

<b>Nutrient requirement*</b>					
<b>Nutrient</b>	<b>Locust (100g)DM</b>	<b>Per meal</b>		<b>Daily intake</b>	
		<b>Male</b>	<b>Female</b>	<b>Male</b>	<b>Female</b>
<b>Protein</b>	50.55	15	19	46	56
<b>Fat</b>	29.87	7-12	17-12	20-35	20-35
<b>Fiber</b>	10.94	13	7-9	38	25
<b>Carbohydrate</b>	Nil	34	34	130	130

Note:\*Dietary reference intakes (DRIs): recommended dietary allowances and adequate intakes, minerals, Food and Nutrition Board.

Source: Food and Nutrition Board, Institute of Medicine, National Academies (2005).

Appendix 2: Recommended intake of essential minerals per day compared with the locust (*Schistocerca gregaria*) .

<b>Minerals intake</b>	<b>recommendation for 25-year-old males (mg per day )*</b>	<b>Locust (mg/kg)</b>
<b>Sodium</b>	1 500	3 008
<b>Potassium</b>	4700	2 651
<b>Calcium</b>	1 000	249.6
<b>Magnesium</b>	400	370
<b>Iron</b>	8	31

Note:\*Dietary reference intakes (DRIs): recommended dietary allowances and adequate intakes, minerals, Food and Nutrition Board.

Source: Food and Nutrition Board ,Institute of Medicine, National Academies (2005).