

**EDIBLE INSECT AS A TRADITIONAL FOOD SOURCE AMONG THE AKANS IN
SOUTHERN GHANA.**

BY

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DECLARATION

This is to certify that this work is the result of my own research undertaken by me, Shadrack Kwaku Debrah towards the award of Master of Philosophy in Entomology at the African Regional Postgraduate Programme in Insect Science (ARPPIS) of the University of Ghana, Legon. This thesis has not been submitted for any degree and all the authors whose works served as a source of information for my work have been dully acknowledged by way of referencing.

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ABSTRACT

The African palm weevil, *Rhynchophorous phoenicis* larva is a popular delicacy among the Akans of Ghana and consumption of this insect is an important tradition in the Birim South, East Akim and Kwahu West districts all in Southern Ghana. Closed and open ended questionnaires were administered in these districts to investigate the main edible insects eaten and their perception about entomophagy. The African palm weevil was the main insect named by this group and out of a total of 500 respondents interviewed in this survey, 92.4% (462) actively consumed *R. phoenicis*. 8.3% (42) indicated that entomophagy was primitive. 1.2% (6) of the respondents interviewed consumed the pupae whilst 11.3% (57) consumed the adult. 87.5% (437) preferred to feed on the larvae (grub). 54.1% (270) of the respondents regularly consumed the larvae as part of their diet, 10.5% (53) of respondents consumed it because of its flavor and 7.6% (38) consumed it out of curiosity. 27.8% (139) indicated that the larvae were very nutritious. Laboratory experiment was also carried out to evaluate suitable substrates and appropriate temperatures for rearing *Rhynchophorous phoenicis*. Three substrates, palm heart, raphia palm and sugarcane slices were soaked for a period of three days to soften it. Three pairs of unmated adult weevils were sexed based on a series of black hair at the tail end of the snout and placed on each substrate for mating. The insects were reared at different temperatures, $24 \pm 2^\circ\text{C}$, 70 ± 5 ; $20 \pm 2^\circ\text{C}$, 70 ± 5 and $28 \pm 2^\circ\text{C}$, 70 ± 5 . After mating, females were transferred into oviposition bowls filled with each substrate. Eggs laid were counted under microscope and transferred into their respective substrates for observation. Parameters like, female fecundity, percentage hatchability, larval period, pupation period, successful adult emergence and longevity span of *R. phoenicis* were observed. Higher amount of eggs laid (122.60 ± 7.4) and percentage hatchability of 95.5% were recorded on palm heart compared to the other substrates at $24 \pm 2^\circ\text{C}$,

70 ± 5 R.H with larval period and longevity of *R. phoenicis* being shortest. Sugarcane slices were the most suitable substrate for pupation with the highest adult emergence of 18.20 ± 0.5 at $20 \pm 2^\circ\text{C}$, 70 ± 5 R.H. However, the life cycle of *R. phoenicis* was shorter at $24 \pm 2^\circ\text{C}$, 70 ± 5 R.H on palm heart. Sensory analyses of *R. phoenicis* with other meat samples were done and 10 panelists were trained to evaluate the samples. After the training, panelists agreed on some meat characteristics and were scored on a scale of five. Significant differences ($P > 0.05$) occurred in the acceptability of the samples with panelists showing more preference for *R. phoenicis*.



DEDICATION

This thesis is dedicated to my family and friends for their care, support and understanding.



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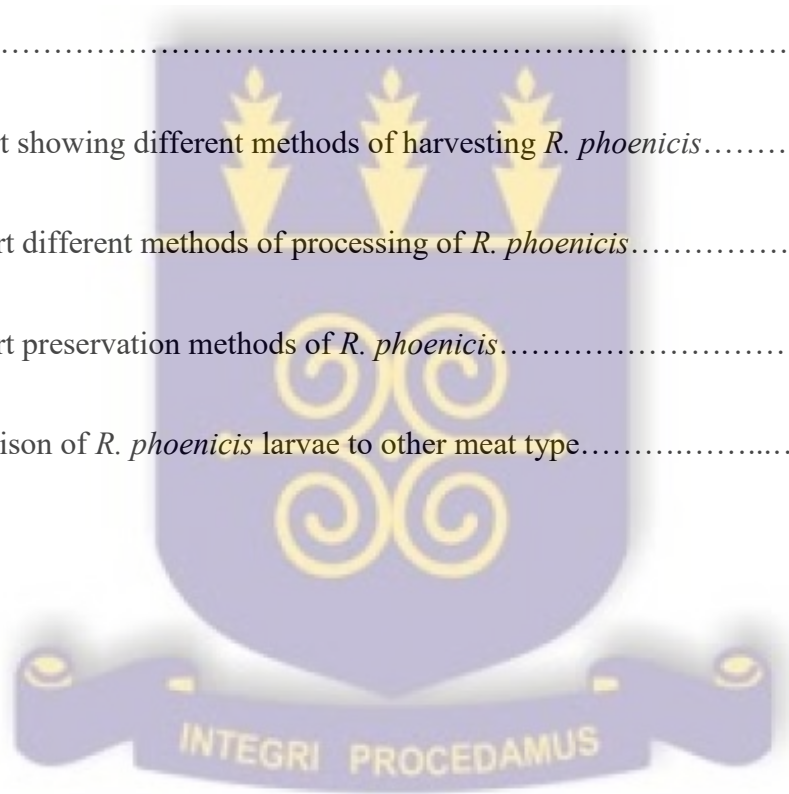
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CHAPTER ONE

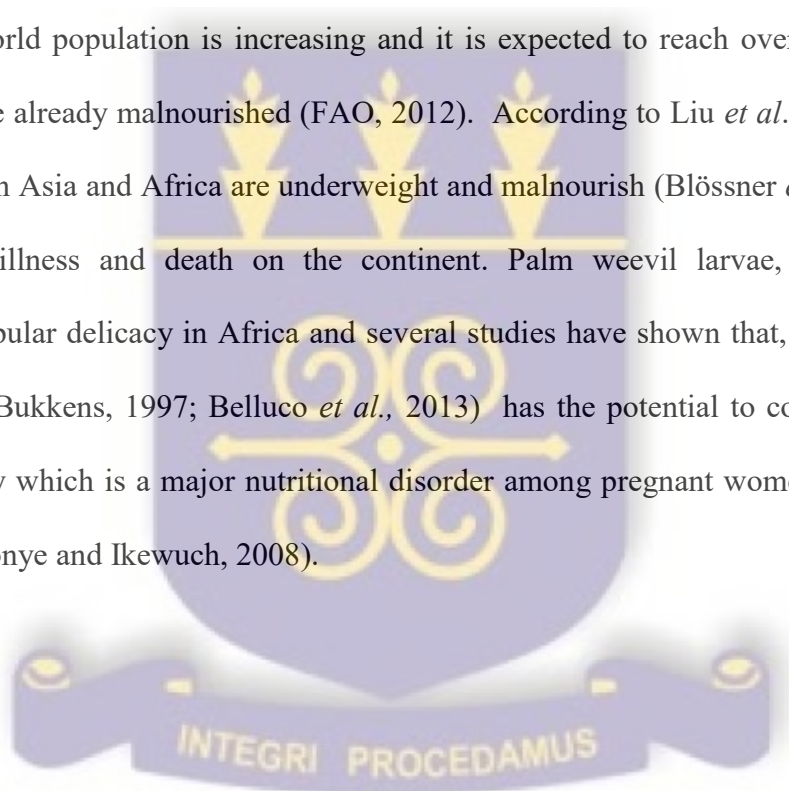
1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

Insects are the most successful group of organism in the animal kingdom with high biodiversity (Durst *et al.*, 2010) especially the terrestrial and freshwater in terms of species richness, animal biomass and critical ecological functions (Samways, 2005). Insects are valuable to humans due to their pollinating activities and their use as biological control agents has aided in the control of pests (Choate and Drummond, 2011). Some insects provide commercial value products such as honey and silk for human and animal. Bees deliver about 1.2 million tonnes of commercial honey per year (FAO, 2009), whilst silkworms produced more than 90,000 tonnes of silk (Yongwoo, 1999). Carmine, a red dye produced by scale insects (Hemiptera), is used to colour foods, textiles and pharmaceuticals, while resilin is used in medicine to repair arteries because of its elastic properties (Elvin *et al.*, 2005). Lewis (1992) reported that, the use of silk proteins of arthropods as biomaterials has inspired technology and engineering methods. According to Pemberton, (1999) arthropods as parts of folk medicinal remedies continued to be important in China and Korea as they were generally regarded as a source for the development of drugs with immunological, analgesic, antibacterial, diuretic, anesthetic, and anti-rheumatic properties (Yamakawa, 1998). Besides their commercial and medicinal value, insects also constitute an important component of the diet of many cultures around the world and their consumption makes efficient use of available natural resources (Ana Mari'a Acun~ *et al.*, 2011). Ulysse Aldovandi, an Italian entomologist reported that insects were part of Asian food items in 1602. Recently, it has also been established that insects are important natural source of food for many vertebrate animals, including birds, lizards, snakes, amphibians, insectivores and other mammals (Banjo *et al.*, 2010). The traditional use of insects as food continues to be widespread in the tropical and

subtropical countries as it provides significant nutritional, economic, and ecological benefits for rural communities. Many of these countries regularly eat insects as part of their diet, particularly in Africa and Asia (Manary and Sandige, 2008; Nonaka, 2009; Ramos-Elorduy, 2009; Gahukar, 2011). In Kenya where malnutrition is prevalent, studies have shown that wheat buns enriched with insects are actually preferred by the locals over ordinary bread as they provide a significant nutritional contribution, especially during times of drought and famine (Gahukar, 2011).

Moreover, the world population is increasing and it is expected to reach over 9 billion as 870 million people are already malnourished (FAO, 2012). According to Liu *et al.* (2012), one-third of children born in Asia and Africa are underweight and malnourish (Blössner *et al.*, 2005) and a major cause of illness and death on the continent. Palm weevil larvae, *Rhynchophorous phoenicis* is a popular delicacy in Africa and several studies have shown that, *R. phoenicis* as a traditional food (Bukkens, 1997; Belluco *et al.*, 2013) has the potential to combat hunger and anemia deficiency which is a major nutritional disorder among pregnant women on the African continent (Okaraonye and Ikewuch, 2008).



1.2 Justification

Promoting *Rhynchophorous phoenicis* as a traditional food among the average people living in remote areas can help minimize malnutrition and disease problems across Africa (DeFoliart, 2002). Several *Rhynchophorous spp* are edible at some stages of their life cycle (Illgner and Nel, 2000) as they provide essential nutrients such as proteins, carbohydrates, fats, minerals and some vitamins for body development (Capinera, 2004). Van Huis (2013) reported that the consumption of *R. phoenicis* provides 76% of protein and 100% of vitamin of the total body requirement. In many developing countries and among various cultures throughout the world, *R. phoenicis* remain vital and preferred food source of protein, fat, minerals and vitamins (Nonaka, 2009). According to Ramos-Elorduy, (2005), *R. phoenicis* contains 23-36g of protein. These quantities of protein have been estimated to be more than the protein in grounded beef (27.4g) and cod fish 28.5g (Banjo *et al.*, 2006; Okaraonye and Ikewuchi, 2008).

Despite the substantial efforts made in Ghana to increase food production, there is a very serious food insecurity problem nationwide due to foodstuff deficiency affecting low income groups living in rural areas, while many sources of staple foods have not been research in spite of their enormous importance for a very large group of people. Entomophagy in Ghana may be a good option and farming of *Rhynchophorous phoenicis* for food can improve food and nutrition insecurity among the habitants in the Southern part of the regions as it often consume among the inhabitants in the region.

1.3 Objective

To determine the potential of *R. phoenicis* in reducing food insecurity in Southern Ghana.

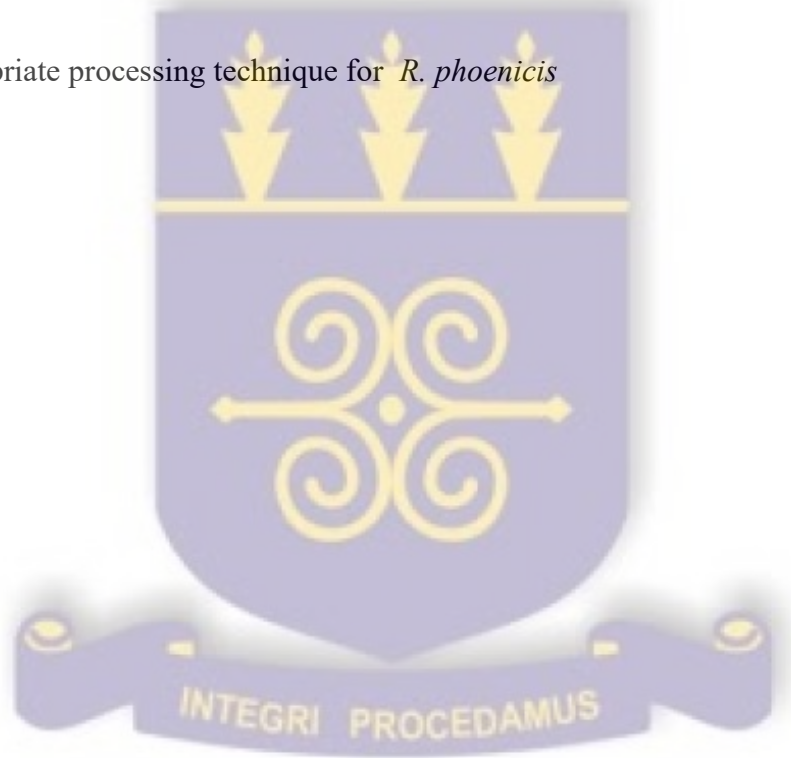
1.4 Specific objectives

To determine the traditional knowledge associated with consumption of *R. phoenicis*.

To evaluate different substrates for rearing *R. phoenicis*.

To determine the most suitable temperature for the development of *R. phoenicis*.

Determine appropriate processing technique for *R. phoenicis*



CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 GLOBAL PERCEPTION ABOUT CONSUMPTION OF EDIBLE INSECTS

Despite the current trends in developing new food product, eating of insects has always been unacceptable to the developed countries (FAO, 2010). Many people in the Western societies, regard entomophagy as disgusting and primitive behaviour (FAO, 2013) and it is the main reason why the butterfly moths are not very popular in Los Reyes Metzontla in Mexico, because they strongly believe that, they resemble snakes (Acuña *et al.*, 2011). In the middle East where sheep, goats, pigs and cattles were first domesticated, insects are seen as minor food source and not competitive food items (DeFoliart, 2003) which has contributed to the reason why insect rearing has been neglected in agricultural research in that part of the world (FAO, 2013). Moreover, when new food products are introduced in an area, it induces fear (Pliner and Salvy, 2006). Schösler *et al.* (2012) described a case in Europe where edible insects were rejected due to lack of knowledge on their origin and post-ingestional consequence. Behavioural studies with some students in America showed that majority of the students were able to touch the insects with their hands and not their lips (Schösler *et al.*, 2012).

The African palm weevil, *Rhynchophorus phoenicis*, with body length of about 25 mm is widespread throughout tropical and equatorial Africa, from Senegal to Ethiopia and South Africa. These large beetles were considered as serious pest in palm plantations, particularly damaging young palms, mainly *Cocos nucifera*, *Metroxys lonsagu*, *Raphia* species, *Elaeis guineensis* and *Phoenix dactylifera*. Most of the inhabitants in these countries believe that collection of this insect from the field reduces the damage they cause as well as the use of pesticides as a means of sustainable crop protection (Yen, 2009).

Today, entomophagy is becoming interesting worldwide, not only in countries with historically long term consumption of insects, such as Mexico (Ramos-Elorduy, 2009a; Acuña *et al.*, 2011), Japan (Nonaka, 2009) and China (Chen *et al.*, 2009) but also some European countries have been noted for their consumption (Ramos-Elorduy, 2005). About 2000 species of insects are consumed by 3071 ethnic groups worldwide (Ramos-Elorduy, 2009b) and entomophagy has been extensively adopted by many people in developing countries (Cherry, 1991; Latham, 2001; De Foliart, 2002). The Jotis ethnic group in Venezuela cultivates palm weevil larvae by manipulating insect resources for human consumption (Mitsubishi, 1988). The larvae of butterflies and moths are mostly consumed in countries like Democratic Republic of Congo, Congo, Angola, Zimbabwe, and South Africa (DeFoliart, 1999). According to the FAO (2010), some insects in their dried form, have twice the protein of raw meat and fish, whilst others, especially in the larval stage, are also rich in fat and contain important vitamins and minerals. These insects have high nutritional value with low cholesterol content allowing for the enhancement of improved human nutrition (Lopez and Shanley, 2004). In Nigeria, the pallid moth of the Shea butter tree *Vitellaria paradoxa* is a special type of food in many homes in the country (Nongo, 2005). The indigenous families gather these insects and sell them in the market to make a living (Adeduntan and Bada, 2004). It is further reported that in South Africa, 1600 tonnes of the Emperor moth *Gonimbrasia belina* (Lepidoptera) is sold in a year, selling at a price between 20-150 South African Rand per 50 kg bag (Agbidye *et al.*, 2009). A world map showing areas of insects consumption (plate: A)

2.1.1 A world map showing edible insects consumption areas

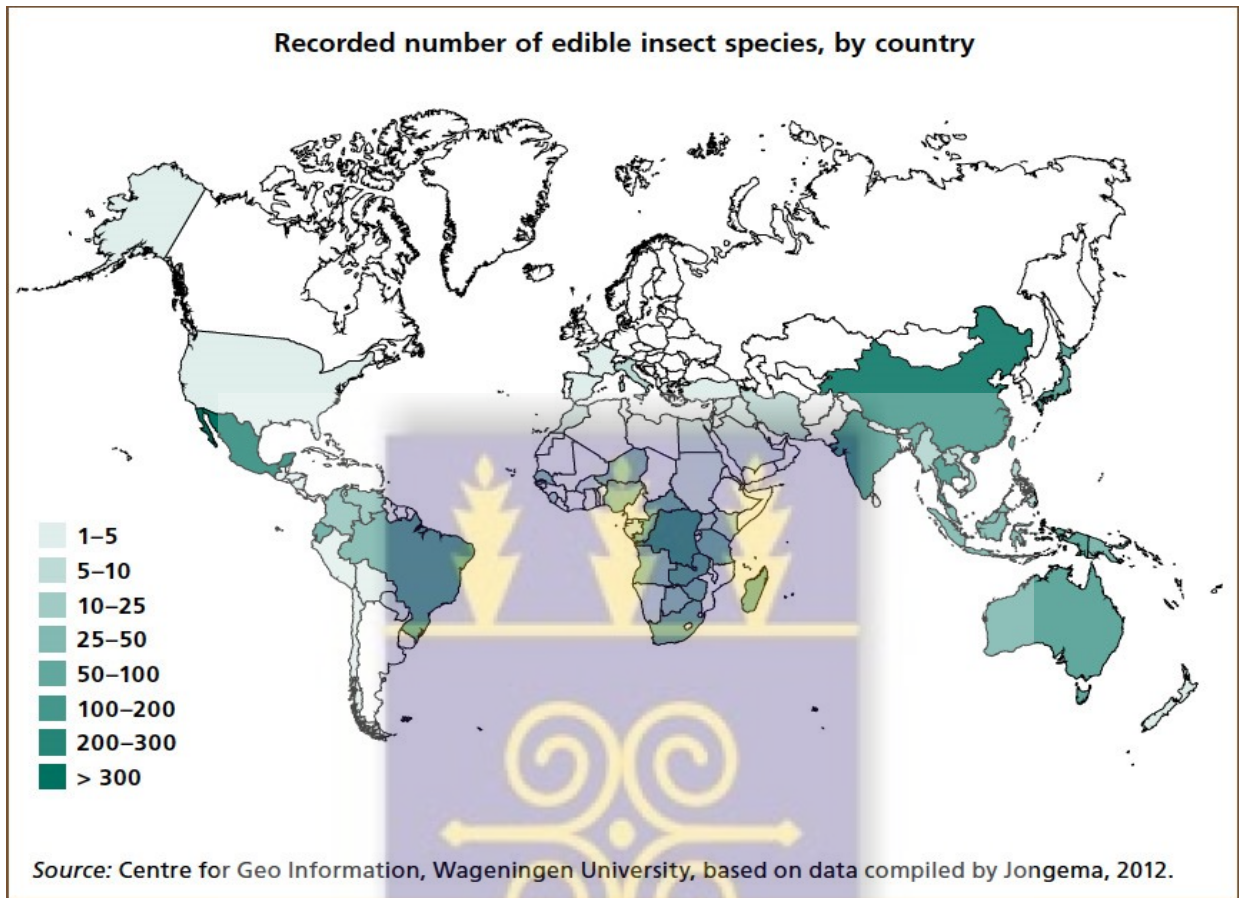


Plate A: Areas of insects consumption

2.2 HISTORY OF EDIBLE INSECTS IN AFRICA

Different communities in Africa consume different kinds of insect species. For example, the Mbunda in Angola, Zambia and Namibia have been reported to consume about 31 species of insects (Christensen *et al.*, 2006; Hoare, 2007). In DR Congo, Takeda, (1990) reported that, 21 species are consumed by the people of Ngandu. In many parts of Africa, entomophagy is practiced as a traditional heritage and literature have shown that entomophagy on the African continent started before the 20th century (Christensen *et al.*, 2006; Hoare, 2007).

The indigenous people of Gbaya in the Central African Republic were said to have consumed about 96 different species of insects which amounts to 15% of their daily protein intake whilst the Bembas in Northern Zambia, Southern DRC and North-Eastern Zimbabwe also feed on about 30 different species of insects (Hoare, 2007). In Kenya, insects such as lake flies, ‘agoro’ termites, black ants, crickets, and grasshoppers, form part of traditionally consumed meals in the Western part of the country where entomophagy is very popular, 164 insect species are collected and sold in markets (Ayieko *et al.*, 2012), .

The early hominids, in Southern Africa, used bones as a tool to harvest termites from holes million years ago (Blackwell and d’Errico, 2001). They pushed objects into hills, forcing termites out, although capture by destruction of termite hill was most preferred (Blackwell and d’Errico, 2001). The Gbaya in the Central African Republic (Joulian and Roulon-Doko, 1994) swept the savanna vegetation which had been cut the day before, to harvest termites (Roulon-Doko, 1998). Some entomophagous species consumed in Africa (Table: 1)

Table 1: List of some entomophagous species consume in Africa.

Species	Countries
<i>Rhynchophorus phoenicis Fabricious</i>	Angola, Nigeria, Cameroun, Congo, Ghana
<i>Acanthophorus maculatus</i> Lameere	Zambia
<i>Petrognatha gigas</i> Fabrious	Senegal
<i>Tricholepsis</i> spp	Madagascar
<i>Natalicola delegorguei</i> Spin.	South Africa
<i>Sadaka radiata</i> Karsch	D.R. Congo
<i>Oecophylla</i> spp	Botswana ,Cameroun, Congo
<i>Macrotermes</i> spp.	Tanzania, D.R. Congo
<i>Saturnia marchii</i>	Gabon
<i>Exopropacris modica</i> Karsch	Cameroun

Source: Van Huis, 2003

2.3 ENTOMOPHAGY IN GHANA

Consumption of insects in Ghana raises eyebrows among certain ethnic groups and acceptability to consume depends largely on one's cultural background. Currently entomophagy has been report across the ten regions of the country (Anankware *et al.*, 2015). Different insect species are consumed in different region based on their distribution and factors that affect their seasonality. For example the pallid moth of the Shea butter tree, *Vitellaria paradoxa* is mostly consumed in the three Northern regions of Ghana (Anankware *et al.*, 2015). Examples of some edible insects are found below.

2.3.1 Palm weevil

The African Palm weevil larvae feed on dead palm trees. Some indigenous people in Southern Ghana deliberately fell palm trees in search of the larvae. This felled tree serves as breeding grounds for the larvae and this practice is common among the Akans. However, in recent times, it has become more challenging to harvest the larvae from the wild because most palm plantations are sprayed with insecticide and it is thought that this reduces their availability. Researching into different method of rearing palm weevil larvae (*R. phoenicis*) in a more sustainable manner without felling the trees holds an answer to their readily availability (Anankware *et al.*, 2013)

2.3.2 Termites

Eradicating poverty and hunger on the African continent remains the objective of the Food and Agricultural Organization of the United Nations, and promoting winged termites as traditional food (Niaba *et al.*, 2012) can help achieve this goal. Termites are consumed in most of the ten regions of Ghana. These insects are harvested during the raining season with water traps. This practice is also common in Cote d'Ivoire (Niaba *et al.*, 2012) and research indicates that the

nutritional components of termites are higher than fish and red meat. However, culturing of termites is very difficult and should not be encouraged due to their high emission of methane.

2.3.3 Larvae of the black soldier flies

The black soldier fly (*Hermetia illucens* Linnaeus) (Diptera: Stratiomyidae) pupae contain 35% fat and 42% protein and live pupae contains 44% of dry matter and can easily be stored for long periods. These flies are good for animal consumption (Van Huis, 2013).

2.3.4 Grasshoppers

Protein is a key component in insect nutrition and grasshopper (Orthoptera) is not exception. Grasshopper contains 77.13% of protein and can supply the daily protein needs of human and their value added product in protein is higher than plants. Kenis and Hein, (2014) reported that, this insect can be transform into food supplement particularly for nursing mother. Insects and major consumption areas in Ghana (Table: 2)

Table 2: List of insects and major consumption areas in Ghana

Insects	Areas of consumption in Ghana
palm weevil larva	Southern Ghana
Wing termites	Northern and Southern Ghana
Grasshopper	Northern Ghana
Cricket	Northern Ghana

Source: Anankware *et al.*, 2013

2.4 ECONOMIC IMPORTANCE OF EDIBLE INSECTS

Insects in their natural environment provide certain beneficial ecological services to mankind. Organisms involved in this interaction contribute towards the achievement of food security, improving the nutritional status of humans and removal of waste materials from the environment (Blackwell and d'Errico, 2001). At the same time some of these insects also cause severe damages to plants reducing the economic value of the host plant. Palm weevil was discovered as a serious pest of coconut plant in India (Lefroy,1906; Nirula,1956) and 17 species of the palm weevil were reported in 50% of date palm growing countries (Faleiro, 2006). The weevil attacks the growing point of palm plant and eventually causes it to decay. For the past 30 years, the palm weevil has caused huge economic losses in date palm worldwide (Faleiro, 2006) due to its active borrowing nature into the internal tissues of the palm plant which has led to the dead of the many plant in major cultivation areas (Abraham *et al.*, 1998).

According to Hunsberger *et al.* (2000), the damage caused by *R. cruentatus* in *P. canariensis* plantation was estimated between \$285,000 - \$380,000 in a nursery in South East Florida. Damages such as, tunnels at the base of the leaves and trunks, yellowish fluid oozing out of the tree, emission of fermented odor from an infected plant made by the feeding grubs show how severely the palm plant was infested in the nursery (Abraham *et al.*,1998). Recently harvesting of *R. phoenicis* larvae for consumption and marketing purposes have become common in certain countries in West and Central Africa providing some income to support household expenditures in the rural areas. These insects are sold in market areas in Cameroon; eg by roadside and vendors at Mvog-mbi, Mvog-ada, Nkondongo, Bertoua, Abong-Mbang, Ayous and Mbalmayo (Muafor *et al.*, 2015). In these markets, larvae are sold between 25 to 30 pieces as one item for XAF 500 (USD 1) in Abong-Mbang and XAF 1500 (USD 3) in Yaoundé and Douala (Muafor *et*

al., 2015). Monzenga *et al.* (2015), described marketing of *R. phoenicis* in Africa as a very lucrative business as a set of four medium size (2kg) larvae are sold at a price of Fc 300-350 (\$ 0.33- 0.39).

Several species of leaf-footed plant bugs *Leptoglossus phyllopus* are also capable of limiting the expansion of fruit production in the world (Pemberton, 1999). Like many other *Leptoglossus* species, *L. australis* has recently become pest of a wide range of crops including citrus, mango, legumes, tomato, cocoa, and sorghum in most part of the world except the Western Hemisphere (Pemberton, 1999) causing dryness in the affected wedges of the fruit and produces bad fruit flavour. *Hydrellia philippina* Ferino (Ephydridae: Diptera) larvae attack the base of the leaf of rice plants. The damage caused by this insect is characterized by narrow stripes in the leaf margins leading to distortion and stunted growth of the rice plant (Pemberton, 1999). *Nilaparvata lugens* (Delphacidae: Homoptera) are ochraceous brown ventrally and dorsal. The larvae and adults infest rice plant at the base of the leaf. Early infestation causes brownish and yellowish patches on the leaves (Navarajan, 2007). *Rhizopertha dominica* (Fabricius) infest wide range of stored grains. It became a serious pest in the USA during the World War I as the larvae feed on the endosperm of grains making it unattractive for human consumption. However, these insects have become a traditional meal in most homes in Africa. Hanboonsong *et al.* (2013) reported that, 10 kilograms of *Nomadacris succincta* and *Rhizopertha dominica* (Fabricius) were sold for THB354/kilogram (USD 9.9). Large numbers of water giant bugs were also imported from Myanmar and neighboring countries due to their high demand in Thailand. The demand for male water giant bugs were found to be high compared to females with price ranging from THB10 (USD 0.28) to THB15 (USD 0.42) in 2011 (Hanboonsong *et al.*, 2013). Grasshoppers cause serve havoc to most plant species across Africa and Asia. These are eaten in some

countries. According to Ratanachan, (2009) 170 tonnes of grasshoppers are imported from Cambodia into Thailand. These were sold in frozen packages throughout the country by traders to food vendors. The commercializations of full grown larvae of grasshoppers are done more frequently through retailers and wholesalers (Vantomme *et al.*, 2004) in certain African countries. The larvae are sold according to their weight especially to restaurant operators at a price which is more expensive than meat (Hanboonsong *et al.*, 2013). According to Tabuna (2000) some restaurants in urban areas in the Central Africa also serve grasshopper as part of their menu.

2.5 THE ROLE OF EDIBLE INSECTS IN FOOD SECURITY

Insect farming is one of the many ways of addressing food and nutrition insecurity issues in Africa. Insects reproduce very quickly with high growth and higher feed conversion rates and very low environmental effect (www.fao.org/forestry/edibleinsects/en/). Globally, 1,900 species of insects are consumed by about 2 billion people in the developing countries (Huis, 2013), due to rapid urbanization in developing countries and the shift in composition of global food demand as insects play an essential role in minimizing food insecurity (Kelemu *et al.*, 2015).

Harvesting and sale of edible insects play active roles in improving the standard of living among the average Ghanaian in the rural areas. For example, collection of palm weevil larvae and pupae by women living in rural areas serves as a source of income for basic household expenditure (Agea *et al.*, 2008; Hope *et al.*, 2009) with significant contribution in alleviating malnutrition and hunger in Africa (Vantomme *et al.*, 2004; Ayieko *et al.*, 2010). In the Northern region of Ghana, especially Navrongo and its environments, termites are sold in the market (Anankware *et al.*, 2015) as a means of generating income to support the families in household expenditure. Furthermore, the Department of National Parks and Wildlife in Malawi in the year

1990 allowed some indigenes living around the Kasungu national park to harvest caterpillars from the park and also incorporated beekeeping in the park as a way of generating income and achieving food security in the communities around the Kasungu national park (DeFoliart, 1999). These insects are now being packaged and sold on the market in Europe and North America as they deliver adequate quantities of healthy protein (DeFoliart, 1999). These insects are prepared in the form of snacks and sold alongside other meat products like poultry eggs and pork (Agbidye *et al.*, 2009).

2.6 NUTRITIONAL VALUES OF EDIBLE INSECTS

The proportion of protein and fat in some insects are much greater than that of beef and fish with high energy content. Insects such as caterpillars are rich in minerals such as calcium, zinc, iron, and magnesium and phosphorous as well as vitamins. Several works have also indicated that due to their high nutritional value, 100gm of insects can provide more than 100% of the daily requirements of vitamins and minerals in human (Srivastava *et al.*, 2009). In some regions in Africa, caterpillar flour is mixed with other food to solve problems of malnutrition in children. The red ant is essentially rich in calcium for building strong bones in the anemic and weaker individual (Srivastava *et al.*, 2009). *Rhynchophorous phoenicis* larvae have 17 amino acids excluding glutamic acid (15.20g/100g) and tryptophan as the predominant amino acids. The larvae have high values of leucine (8.04g/100g), phenylalanine (5.24g/100g), lysine (8.32g/100g) and arginine (6.47g/100g) compared to the lower values of lysine from certain leguminous crops such as cowpea (2.8g/100g) (Aremu *et al.*, 2006) and soybean (6.40g/100g) (Iwe, 2003). Pellett and Young (1990) observed that, these appreciable amino acids plays a crucial role in the human body compared to those obtained from beef and goat. Nutritional values of different insects (Table 3)

Table 3: Nutritional values of different insects

Insects	Protein (gm)	Fat (gm)	Calcium (gm)	Iron (gm)
Red ant	13.9	3.5	47.8	5.7
Cricket	21.32	6.01	75.8	9.5
Dung beetle	17.2	4.3	30.9	7.7
Grasshopper	20.6	6.1	35.2	5.0
Termites	6.1	N/A	N/A	35.5
Weevil	6.7	N/A	N/A	13.1

N/A- Not Analyzed; Source; Srivastava *et al.*, 2009.

2.7 IMPACT OF EDIBLE INSECTS ON THE ENVIRONMENT

Waste materials from production and other agricultural institutions are currently becoming a problem in Africa and other parts of the world. These wastes contribute to environmental pollution and contamination of soil and water bodies (Mallin and Cahoon, 2003). The poultry and livestock industry in Nigeria produce 932.5 tonnes of manure annually (Adejinmi, 2000) and recycling of this waste has an important role in agriculture. However, global demand for poultry and livestock according to FAO (2006) is expected to increase by the year 2050. Technologies such as liquid and solid fractions separation, aerobic or anaerobic digestion, composting and fermentation have been proposed as a way of recycling these waste materials (Sa'nchez, 2001; Sorokoletov, 2006). Dipteran degrades organic matter from their faeces and transforms it into biomass (Cic'kova *et al.*, 2012). The larvae of this group have high reproductive capacity and develop on wide range of material (Putman, 1983). The degrading potential of this group have been evaluated in terms of recycling of manure produced by livestock (Cic'kova *et al.*, 2012). The black soldier fly is useful for managing organic waste (Zhang *et al.*, 2010) as its larvae

reduces manure accumulation and nitrogen concentration by 50% (Meyers *et al.*, 2008). Greenhouse emission of gases has become a major concern. Gerber *et al.* (2013) observed that livestock production contribute to 14% of greenhouse gas emission. In contrast, Ooninx *et al.* (2010) reported that entomophagous species contribution of ammonia production and greenhouse gas emission to global warming is very low compared to livestock production. However, mass rearing of these insects have the potential of solving waste management problem whilst improving human and environmental health (Kelemu *et al.*, 2015).

2.8 HARVESTING, PROCESSING AND PRESERVATION OF MAJOR EDIBLE INSECTS ORDERS

Over the past few years, edible insects have been used in value-added products such as canned foods and even snacks on a commercial scale (Siriamornpun and Thammapat, 2008). Most of these insects are available seasonally and some preservation methods among the indigenes allow storage of these insects for a longer period of time (Van Huis, 2003). Different orders of insect species are harvested and treated in different ways for preservation.

2.8.1 Lepidoptera

This group of insects is prepared in several ways before marketing. In Northern Zambia, processing of caterpillar for long-term storage involves eviscerating, roasting and sun-drying whilst the irritating hair are burned off before boiling them in salt water (Van Huis, 2013) and packaging them into sacks. The collection of caterpillar as a household food in some part of Africa is mostly done by women and children, climb the trees and sometimes cut the whole plant to enhance collection of these insects (Van Huis, 2013). The roasted moth larvae are often sold in the market and sometimes shipped in tonnes from one country to the other (Srivastava *et al.*, 2009).

2.8.2 Orthoptera

Harvesting of grasshopper in Japan is done early in the morning, when the wings are wet from the morning dew and are starved over night for it to expel faeces from the body (FAO, 2013). Makhado *et al.*, (2009) observed that harvested locusts are dried under the sun and sometimes soaked in water to release certain secretions. Winged termite are often fried in vegetable oil with ingredient such as garlic, onion, pepper, salt and fermented bamboo shoot (Anankware *et al.*, 2013) and preserved in cans in some countries in Asia (Van Huis,2012). The *macrotermes* species of termites are mostly eaten by many people in Africa. The winged termites emerge from their nest after the first rains at the end of the dry season (Van Huis, 2003). These insects are harvested by introducing a palm leave into their holes; the soldiers biting the leaves are fished out, roasted and grounded into paste and mixed with honey for consumption (Paoletti and Dufour, 2005).

2.8.4 Coleoptera

Wide range of coleopteran species is consumed by many people in the world. In Asia and Africa, palm weevil larva (Coleopteran: Curculionidae) is new source of protein or improvement of already existing when used as a feed supplement. The identification of larvae from a dead raphia and oil palm tree in the wild requires some expertise. The indigenes smell the trunk and carefully listen to the sound produced by the larvae as a means of detecting their presence during harvesting (Muaforet *et al.*, 2015). This method is very popular in some villages in the Southern parts of Cameroun as collectors in areas like Ntoun and Abong-Mbang see it as an efficient way of detecting and harvesting the larvae (Muafor *et al.*, 2015). Nonaka (2009) reported that buprestid beetle, *Sternocera orissa* is harvested by the people in the central Kalahari in January during the outbreaks from *Acacia mellifera* leaves and are mostly cooked and served with rice at

the nymphal stage in Thailand. This species of insects are prepared by roasting, steaming and frying in vegetable oil to increase their shelf life (Siriamornpun and Thammapat, 2008).

2.8.5 Diptera

Emperor dragonflies '*Anax imperator*' are collected at the nymphal stage in rice field in DR Congo (Malaisse, 1997) and Thailand (Pemberton, 1995). These insects are preserved and sold in the market by boiling and roasting. Local ways of cooking some selected edible insects (Table:

4)



Table 4: Local ways of cooking some selected edible insects

Insects	Local ways cooking
Ground cricket	Steamed, roasted, curried, fried
Longan stink bug	Roasted, chili paste, curried
Termite	Fried, roasted with salt
True water beetle	Lightly curried, fried and roasted with salt
Water scavenger beetle	Fried and lightly curried
Bamboo caterpillar	lightly curried with vegetables, fried with chili pepper
Cicada	Toasted, fried, Roasted with chili pepper
Weaver ant	Fried with vegetable
June beetle	Fried, Steam, Roasted

Source: Siriamornpun and Thammapat, 2008

2.9 SEASONAL AVAILABILITY OF EDIBLE INSECTS

The seasonal pattern of the abundance of insect is synchronized with availability of food resources which vary with climate (Silva *et al.*, 2011). Seasonal climatic conditions can exert a strong influence on insect abundance. In an ecosystem with clear distinction between rainy and dry seasons, climatic variables are known to be good indicators of population behavior of insects (Wolda, 1988). Herbivorous insects in temperate areas show a remarkable variation in abundance and activity, mainly in response to changes in climatic factors (Wolda, 1988; Speight *et al.* 1999). Such variation also occurs in the tropics, but it is more complex, although it is clear that rainfall, rather than temperature or photoperiod, is more important (Louton *et al.* 1996).

These insects are restricted to certain localities (Nonaka, 2009) due to frequent variations in climatic factors (Silva *et al.*, 2011). Insects belonging to order of Hemiptera and Hymenoptera are mostly high in numbers between November and February (Chakravorty, 2014) while Coleopteran species, being the largest edible insects groups, are abundant between the months of June and September (Chakravorty *et al.*, 2011). The abundance of these insects is influenced by the availability of food (Wolda, 1988) which negatively affects most herbivorous insects especially in the dry season, when there is less food for them to feed (Braby, 1995). Rodriguez (1992) reported that, this variation in availability of food makes the caterpillars of *Picnotema* species (Lepidoptera: Zygaenidae) mostly dormant from the beginning of the wet season to the second half of the dry season. Some insect orders and their seasonal availability (Table: 5)

Table 5: Some insect orders and their seasonal availability

Scientific Name	Order : Family	Seasonal Availability
<i>Vespa affinis</i> <i>Continentalis</i> Bequaert	Hymenoptera : Vespidae	June-October
<i>Oecophylla smaragdina</i>	Hymenoptera: Formicidae	June-October
<i>Lethocerus indicus</i> (Lep. & Serv.)	Hemiptera : Belostomatidae	Whole Year
<i>Laccotrephes ruber</i> (Linn)	Hemiptera : Nepidae	June-October
<i>Bombyx mori</i> Linnaeus	Lepidoptera : Bombycidae	Whole Year
<i>Oecophylla smaragdina</i>	Hymenoptera : Formicidae	February-April
<i>Termes</i> sp.	Isoptera : Termitidae	May-October
<i>Meimuna opalifera</i> Walker	Hemiptera : Cicadidae	May-June
<i>Tessaratomia papillosa</i>	Hemiptera : Tessaratomidae	Whole Year

Sources: Narzari and Sarmah, 2015

Siriamornpun and Thammapat, 2008

2.10 FACTORS AFFECTING SEASONAL AVAILABILITY OF EDIBLE INSECTS

Several factors influence the availability of edible insects. These include vegetation, temperature and human activities.

2.10.1 Vegetation

Insect community conservation and restoration have been identified as important but difficult tasks. The diversity and abundance of edible insects are greatly affected by habitat management since practices like cutting and grazing may change the associated insect community through profound alterations of plant growth (Goulson *et al.*, 2008). Intense grazing can reduce diversity and abundance of arthropod species (Fischer and Lindenmayer, 2007). It has however been shown that, relaxation of this grazing pressure increases species richness and abundance of phytophagous insects like grasshopper and their parasitoids (Garibaldi *et al.*, 2011) in an ecosystem.

2.10.2 Temperature

Insects are exothermic organisms and their body temperature changes approximately with the temperature of their habitats. Temperature is the most important environmental factor influencing their behaviour, distribution, development, survival and reproduction (Huntly, 1991). Depending on the developmental strategy of the insect species, temperature can exert different effects on their development (Bale *et al.*, 2002). Some insects take several years to complete one life cycle, and these insects tend to prefer moderate temperature variability ranging from 20°C to 30°C over the course of their life history. It has been estimated that a 2°C increase in temperature might cause an insect to experience one to five additional life cycles per season (Yamamura and Kiritani, 1998). Bukhari *et al.* (2012) reported that temperature influences the abundance and distribution of certain insects in agriculture land, and variation in population has been observed

to be dependent on temperature which has caused an increase in spider fauna (Bukhari *et al* 2012).

2.10.3 Human activities

Urbanization is fast increasing in many regions and this trend threatens biodiversity and ecosystem in which edible insects dwell in (Garibaldi *et al.*, 2011). Human disturbance, particularly the loss of natural and semi-natural habitats, is regarded as a primary cause of decline in some edible insect species (Aizen and Feinsinger, 2003; Goulson *et al.*, 2008) and mechanisms that decrease reproduction and survival of insects (Fischer and Lindenmayer, 2007). Indeed, recent reviews have highlighted how multiple anthropogenic pressures have led to a decline in wild species (Bukhari *et al* 2012).

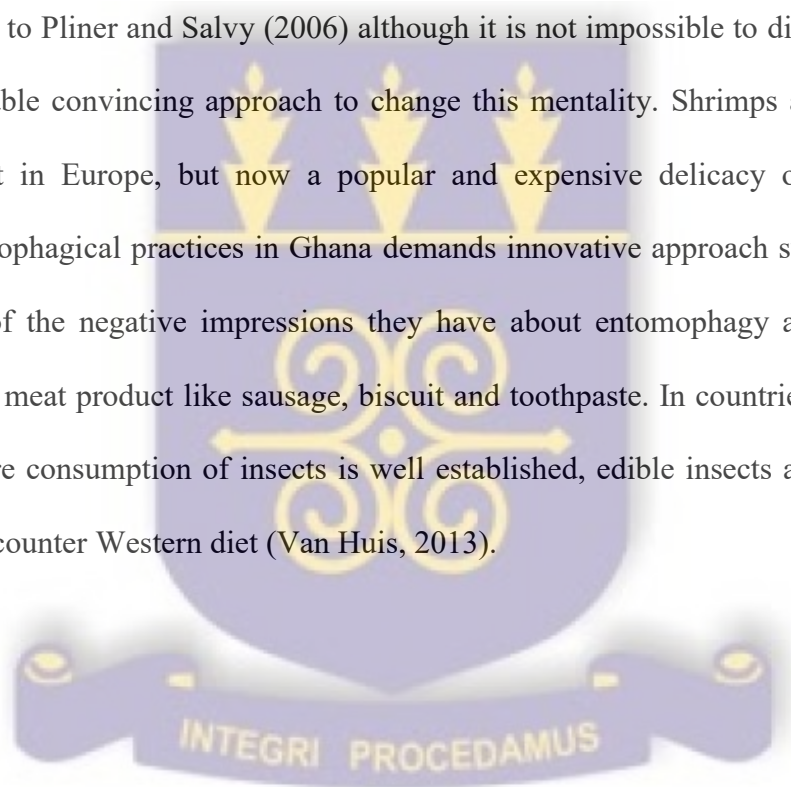
2.11 FUTURE PROSPECTS OF ENTOMOPHAGY IN GHANA

Over 90% of Ghanaian daily protein requirement are imported from overseas, making it unsustainable in our food system (Anankware *et al.*, 2015). Consumption of meat in Africa and the rest of the world has dramatically increased in recent times (Kenis, 2014) and investigating into an alternative source like edible insects holds an answer to food and nutritional insecurity crisis in Ghana. Although insects like grasshoppers, Crickets and the Africa Palm weevil larvae feed on agricultural products which serve as food for human consumption, they provide a substantial amount of protein for humans. A list of edible insects worldwide is given at <http://www.ent.wur.nl/UK/Edible+insects/Worldwide+species>, but traditional knowledge on the associated problems, distribution, economic potential and their utilization is very limited in Ghana. Most insects species used as food over the years in Ghana are either not properly documented or are not published. Fortunately, Anankware *et al.* (2015) embarked on a

nationwide survey to identify major edible insects in the ten regions of Ghana. This has resulted in a successful module for rearing black soldier fly *H. illuscens* and house fly, *M. domestica*

2.12 PROMOTING ENTOMOPHAGY IN GHANA.

Insects are not inferior to chicken, beef and fish in terms of nutrients. The negative attitude toward the consumption of insects in the Western culture contribute towards the misconception that entomophagy in African settings is a survival mechanism prompted by starvation (Van Huis, 2013). According to Pliner and Salvy (2006) although it is not impossible to disabuse this claim, it require reasonable convincing approach to change this mentality. Shrimps and lobsters were poor man's meat in Europe, but now a popular and expensive delicacy on this continent. Promoting entomophagical practices in Ghana demands innovative approach such as disabusing people's minds of the negative impressions they have about entomophagy and processing of insects into other meat product like sausage, biscuit and toothpaste. In countries like DR Congo and Zambia where consumption of insects is well established, edible insects are well packaged and preserved to counter Western diet (Van Huis, 2013).



2.13 BIOLOGY AND LIFE CYCLE OF *RHYNOPHORUS PHOENICIS*

Palm weevil female lay its eggs in the inner core or a cut made on the palm plant (Lefroy, 1906). The egg laying period is between 3 to 5 days after mating. Huston (1922) observed that one female can lay 231 eggs during its life time. However, Monzenga *et al.*, (2015) reported that females will be able to lay up to 531 eggs provided the substrate and the environmental conditions are good during oviposition. The adult has a drilling behaviour by which it creates a deep hole within which eggs are laid. Selection of oviposition site, quality of egg and egg size depend on the host plant (Awmack and Leather, 2002). Several eggs are laid at different points in a hole without clustering together, and are protected by a cemented layer to prevent them from damage (Murphy and Briscoe, 1999). The eggs are white and cylindrical in shape, and possess a special 'gill cover' that provides the developing insect with oxygen. After 2 or 3 days, the eggs hatch into a legless larva which, tunnels through the palm by chewing the softer tissues (Urbano, 2008), by peristaltic movement (Capinera, 2008).

The larvae are found at the various part of the plant, on the crown, near a growing point of the plant and the trunk (EPPO, 2007). The larvae have a minimum of 7 instars (Cabello, 2006), and the number increases with unfavorable conditions before entering the pupal stage. The larval period is between 25 to 105 days (Kaakeh, 2005). When it is mature, it remains in the pupal case (made from the chewed fibers) for a period of two weeks without feeding and pupates inside the case (Ince *et al.*, 2011). Rajamanickam *et al.* (1995) reported that several generations are completed by the weevil within the same host until the tree collapses. The quality of the host plant significantly influences the survival and development of the larvae including the weight, morphology, longevity and reproductive ability of the adult weevil tissues (Urbano, 2008). The

Rhyncophorus palm weevil completes its life cycle from egg to adult between the periods of two to five month (Ince *et al.*, 2011) (Plate: B).

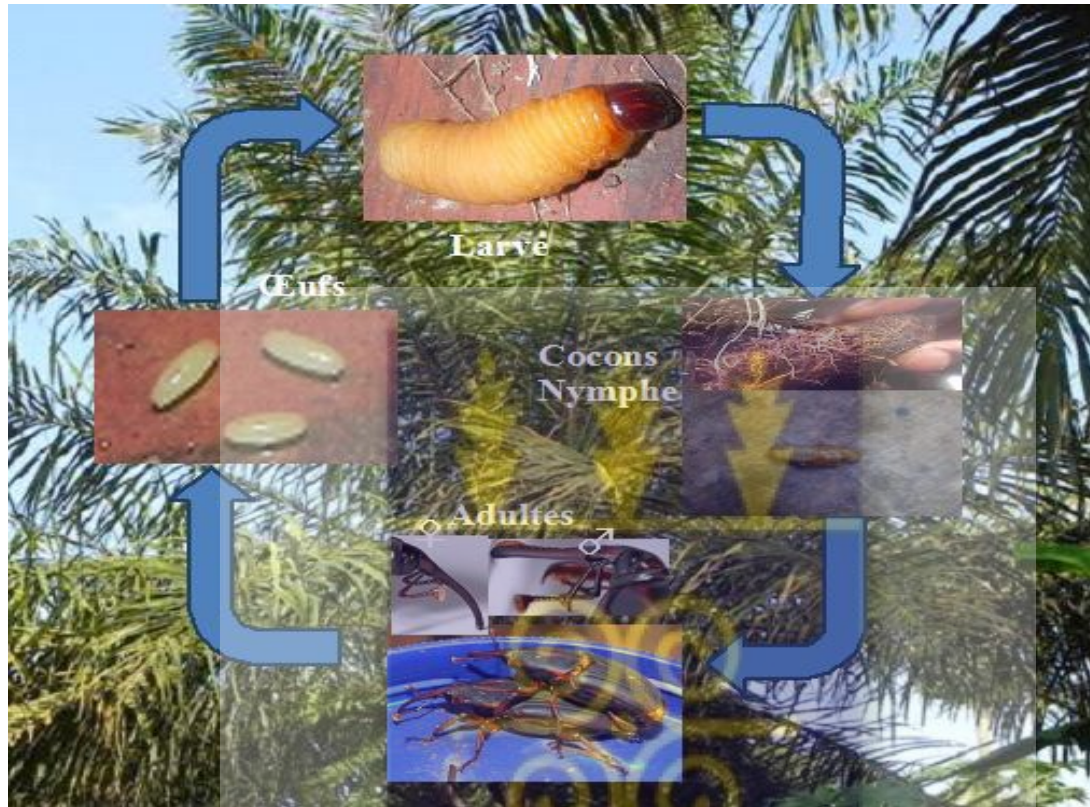


Plate B: life cycle of *R. phoenicis* Source: Monzenga *et al.* (2015)



2.14 FACTORS THAT AFFECT THE DEVELOPMENT OF *RHYNCHOPHORUS* PALM WEEVIL

Several factors have been reported to influence the development of *Rhynchophorus* palm weevil. These include temperature, relative humidity, and moisture content and food type.

2.14.1 Temperature

Temperature is the most important abiotic factor influencing the reproduction, development, survival, behaviour and distribution of *Rhynchophorus palm* weevil. Dembilio and Jacas (2011) reported that the temperature requirement for the development of *R. ferrugineus* (Curculionidae: Coleoptera) has been established recently. A degree day of 40.4 has been documented for the egg laying stage with a lower temperature threshold of 13.1°C. The larvae and pupae require a lower temperature of 15°C and 13°C with a degree day of 666.5 and 282.5, respectively to be able to complete their development (Martín-Molina, 2004). Therefore below these temperatures, fecundity and reproduction of *R. phoenicis* can be impaired.

2.14.2 Relative humidity

Rhynchophorous species typically select conditions of relative humidity that favour their development. Kaakeh (2005) reported that, relative humidity of $70 \pm 5\%$ has shown a significant effect on the fecundity, fertility and longevity of the red palm weevil, *R. phoenicis* Olivier (Coleoptera: Curculionidae) on both artificial and natural diets.

2.14.3 Feeding and food type

The *Rhynchophorus* spp. feed on oil palm (*Elaeis guineensis* Jacq.), Coconut (*Cocos nucifera* L.), Pineapple (*Ananas comosus* Merr.) and Sugarcane (*Saccharum officinarum* L.) (Najeeb, 1988). The adults lay their eggs on the crown where conditions are favorable for hatching. Rearing of these species on oil palm substrate has an environment that is nearly natural with less

microbial contamination and they grow rapidly without any interruption than on an artificial diet. It is more complicated when rearing the palm weevil larva on artificial diet because it requires handling of the delicate larva and daily replacement of diet. The artificial diets are easily contaminated by microorganisms which can result in total failure of the entire colony (AL-Dawood, 2011). However, Kaakeh (2005) reported that Sugarcane bagasse is a good alternative and it has successfully been used for rearing *R. phoenicis* as it is mostly incorporated into feed for feeding young larvae and weaving into cocoon.



CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 PRELIMINARY SURVEY ON TRADITIONAL KNOWLEDGE OF CONSUMPTION OF *R. PHOENICIS*

The survey was conducted in Kwahu West, Birim South and East Akim districts from November to December, 2015 to determine whether *Rhynchophorous phoenicis* (Coleoptera: Curculionidae) has the potential to reduce food insecurity in the Southern Ghana as it is eaten as part of their diet. These are rain forest areas with a distinct dry and rainy seasons and a high relative humidity for most parts of the year. The dry season start from January to March while the rainy season starts from April and ends in November each year. The average temperatures for Kwahu West, Birim South and East Akim districts are 25° C, 32° C and 32° C respectively with an average relative humidity of 70% throughout the year (<http://www.ghana.gov.gh/index.php/about-ghana/regions/eastern-region>). Three communities were selected in each district and a total of 500 respondents were interviewed. Achiase, Anamase and Bieni were selected in Birim South and a total of 199 respondents were interviewed based on the willingness of the individual to participate in the study. 165 and 135 respondents who participated in the survey were from East Akim (Amanfrom, Odumase, Potroase) and Kwahu West (Fodoa, Jejeti, Apesika) respectively. These communities were selected because they are noted for consumption of *Rhynchophorous phoenicis* as food habit and on rare occasion one purchased the larvae from the market. Community entry was done prior to the study and a focus group discussion was held with the participant from September to October 2015. Closed and open ended questionnaire were also administered to determine the traditional knowledge associated with the consumption of *Rhynchophorous phoenicis* (Appendix 1).

3.1.1 A map of Southern Ghana showing the various districts

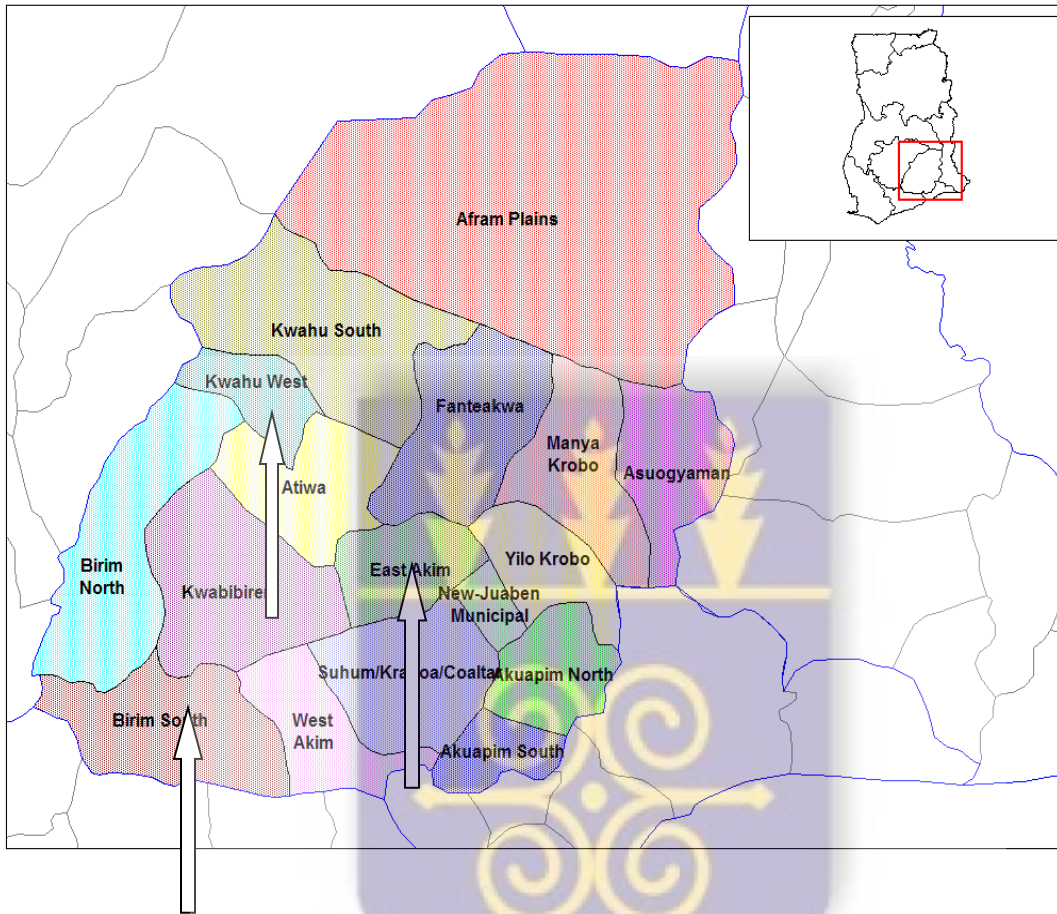


Plate C: A map of Southern Ghana showing the various districts

3.2 LABORATORY EVALUATION OF THE VARIOUS SUBSTRATES FOR REARING *R. PHOENICIS*

The adult weevils used in this study were originally obtained from infested palm trees in Bomfa in the Ashanti region (Plate: H). The weevils were cultured in a rearing room at $24 \pm 2^\circ\text{C}$, $70 \pm 5\%$ RH; $20 \pm 2^\circ\text{C}$, $70 \pm 5\%$ RH and $28 \pm 2^\circ\text{C}$, $70 \pm 5\%$ RH with a constant photoperiod of 12 : 12 (L:D) h (Plate: J) at the Aspire Food Group Research and Development Laboratory Center in Fumesua. The substrates used included 20g pieces each of palm heart, raphia palm and sugarcane slices. These were soaked in water for a period of three days to soften for easy penetration during feeding and egg laying (Plates D, E and F). Adults were sexed after emergence from cocoons based on the presence of a series of black hairs on the frontal part of snouts of the males and which is absent in the females (Al-ayedh, 2008) (Plate: I). Three pairs of unmated adult weevils were placed on each of the substrate for mating and provided with 30mls of sugar solution for feeding (Plate: G and K) immediately after emerging from the cocoons. After two days of mating, females were transferred into oviposition bowls, filled with 20g pieces each of palm heart, raphia palm and sugarcane slices and covered with a wire mesh for egg laying (Plate: K) (Monzenga *et al.*, 2015). The eggs were collected from the oviposition substrates under microscope using camel's hair brush. Eggs from each substrate were counted and placed on their respective oviposition medium; (ie palm heart, raphia palm and sugarcane slices) in a plastic container measuring 30 cm diameter x 20cm deep and covered with a wire mesh measuring 35cm x 35cm. Parameters like, female fecundity, percentage egg hatchability, larval duration, pupation duration, adults emergence and longevity of *R. phoenicis* were observed using the shelf shown in Plate: L. After larval observation, twenty 7th instar larvae each were randomly picked and transferred into a bowl containing fibrous materials of the Palm

heart, raphia palm and sugarcane slices to enable them weave into cocoon. The experiment was replicated five times for the emergence of adults from cocoon.

3.3. Soaked substrates for rearing *R. phoenicis*



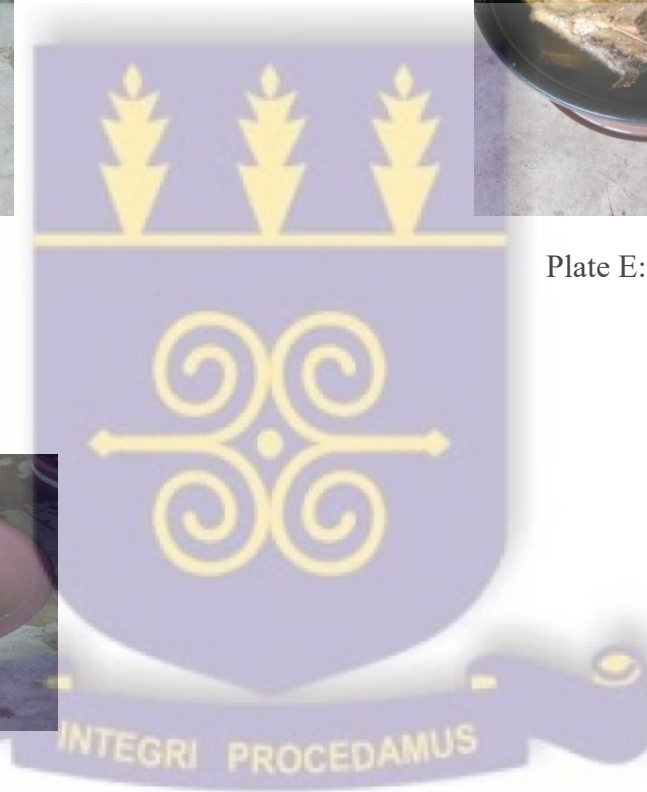
Plate D: Sugarcane slice



Plate E: Palm heart



Plate F: Raphia palm



3.3.1 *R. Phoenicis* adults for evaluation of substrates



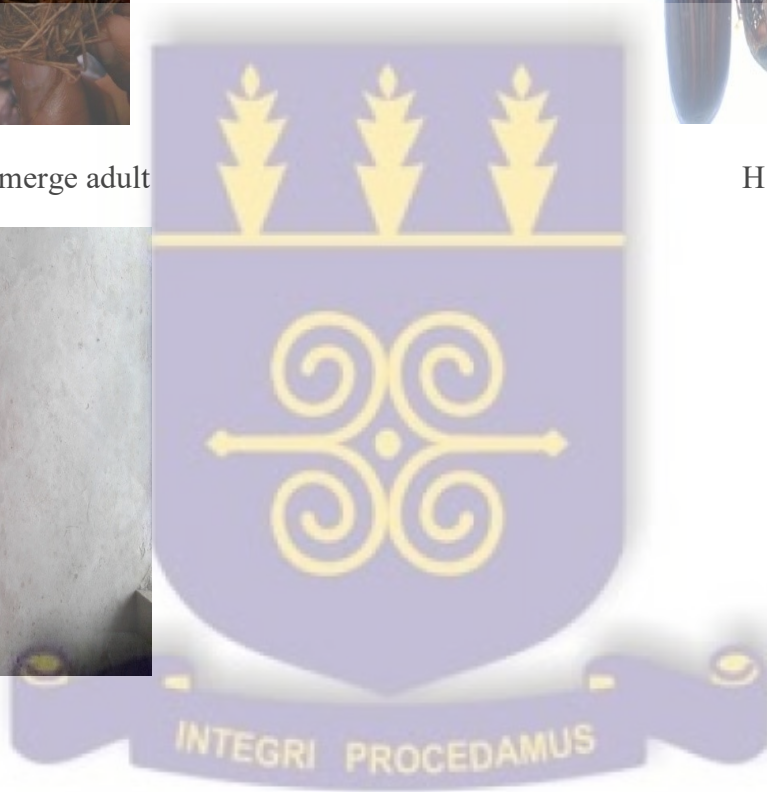
Plate G: Freshly emerge adult



H: Adults



Plate I: Cocoons



3.3.2 Setups for observation of different developmental stages of *R.phoenicis*



Plate J: Hobo onset data logger



Plate K: Cultured *R. phoenicis* females on 20g pieces each of sugarcane, palm heart and raphia palm for egg laying.



Plate L: Laboratory shelf for studying longevity of *R. phoenicis*

The eggs were transferred into small hole made on pieces of raphia, sugarcane and the palm heart with a cork borer. Eggs were covered with their respective pieces of substrate. Eggs were hatched after 2 to 3 days and the larvae duration was studied. The feeds were changed every four days after being degraded by the larvae. The larval duration was studied by counting the number of days it took the first instar larvae to metamorphose to seventh instar whilst the pupation and oviposition durations were also studied by counting the number of days it took the pupae to emerge and lay respectively.

3.4 PROCESSING OF *R. PHOENICIS* LARVAE

Four kilograms each of boneless beef, chicken, beef mixed with *R. phoenicis* larvae, chicken mixed with *R. phoenicis* larvae and *R. phoenicis* larvae alone were used for the experiment. The meat samples were kept in refrigerator for a day to prevent the growth of bacteria and making it unsafe for consumption. The frozen meat samples were thawed at 1°C and cut into pieces using a meat portion cutter through a 5mm sieve. The samples were spiced with 0.5g black pepper, 0.5

red peppers, 0.5g white pepper, and 10g curing salt. 100ml of water was added to each sample and mixed until a uniform mixture was obtained. Raw egg were added to the samples and mixed to bind them together. The mixed meat samples were moulded into circular shapes and grilled. Samples were cut into slices and wrapped into an aluminum foil for sensory evaluate

3.4.1 Processed *R. phoenicis* larvae with other meat products



Plate M: *R. phoenicis* Larvae



Plate N: Chicken



Plate O: Chicken mixed with *R. phoenicis* larvae



Plate P: Beef



Plate Q: Beef mixed with *R. phoenicis* larvae

3.5 SELECTION OF TASTE PANEL

Ten panelists comprising of both males and females aged between 20 and 30 years were randomly selected and trained. During the training, panels were provided with samples (beef, beef mixed with *R. phoenicis* larvae, chicken, chicken mixed with *R. phoenicis* larvae and *R. phoenicis* larvae alone to taste smell and take a critical look at the sample and list all the possible characteristics for each sample. After the training, the ten panelists agreed on six clearly defined sensory characteristics; texture, juiciness, colour, flavour, cohesiveness and acceptability and appropriate reference standard of the sensory evaluation characteristics were scored on a scale of five (5) (Table 7). Taste panelists were served with the slices of the sausages. Bread and water were used as a neutralizer after tasting every sample. Panels were kept at different places to avoid bias during the evaluation.

3.6 SENSORY EVALUATION

Table 6: The sensory evaluation score.

Sensory indicators	SCORES				
	1	2	3	4	5
Taste	Very pleasant	Pleasant	Intermediate	Bitter	Sour
Juiciness	Very juicy	Juicy	Intermediate	Dry	Very weak
Texture	Very smooth	Smooth	Intermediate	Rough	Very rough
Colour	Brown	Light brown	Intermediate	Dark	Very Dark
Flavour	Very strong	Strong	Intermediate	Weak	Very weak
Cohesiveness	Very firm	Firm	Intermediate	Loose	Very loose
Acceptability	Like very much	Like	Intermediate	Dislike	Dislike very much

3.7 Data analysis

The data on survey and laboratory experiment was analyzed by percentage analysis and Analysis of Variance respectively using SPSS version 10.

CHAPTER FOUR

4.0 RESULTS

4.1 PRELIMINARY SURVEY ON TRADITIONAL KNOWLEDGE OF CONSUMPTION OF *R. PHOENICIS*

4.1.2 Educational background of respondents

The five hundred (500) respondents interviewed consisted of 41.2% (218) males and 58.8% (282) females. The age groups were 18 - 29 (29 %), 30 - 39 (32.8 %) and 40-60 (40.2 %). Table (6) shows the level of education of the individual respondents.

Table 6: Level of the individual respondents

Level of education	Number of respondents	Percentage of respondent
Illiterate	129	25.8
Primary School	86	17.1
Secondary school	126	25.2
Tertiary	159	31.9
Total	500	100

100% of the individuals referred to the *R. phoenicis* larvae locally as ‘‘Akokono’’. 78.4% (392) of the respondents sourced their larvae from the wild, whilst 21.6% (108) purchased them from the market. The survey however showed that, Birim South had the highest *R. phoenicis* consumption trend with a percentage of 38.7 % (194) followed by East Akim and Kwahu West with 32.4% (162) and 28.9% (144) respectively.

4.1.3 Perception about consumption of *R. phoenicis*

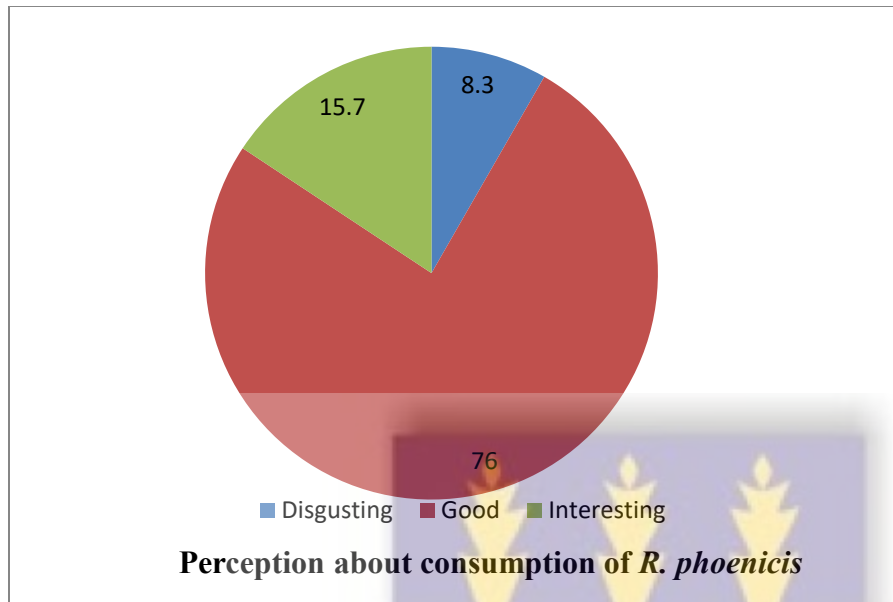


Figure 1: Pie chart showing individual perception about the consumption of *R. phoenicis*

Consumption of *R. phoenicis* was not fully accepted by the people of Birim South, East Akim and Kwahu West as 8.3% (42) of the 500 respondents saw the entomophagy of the palm weevil larva, pupae and adult as primitive. 15.6% (78) of the respondents regarded entomophagy as interesting whilst 76% (380) saw it as good and should be encouraged (Figure 1).

4.1.4 Seasonal availability of *R. phoenicis*

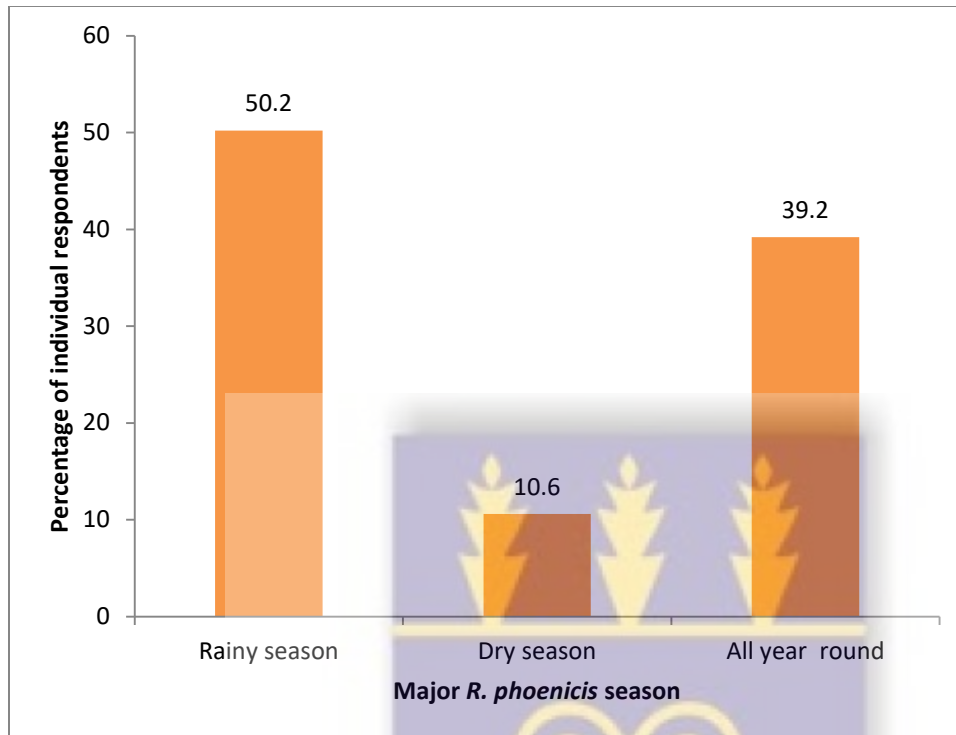


Figure 2: Bar chart showing seasonal availability of *R. phoenicis*

50.2% (251) and 10.6% (53) of the respondents indicated that, the *R. phoenicis* larvae were mostly abundant during the rainy season and at the onset of the dry season respectively with 39.2% (196) of the individuals indicating that, the weevil could be found all year round (Figure 2).

4.1.5 Reasons for consumption of *R. phoenicis*

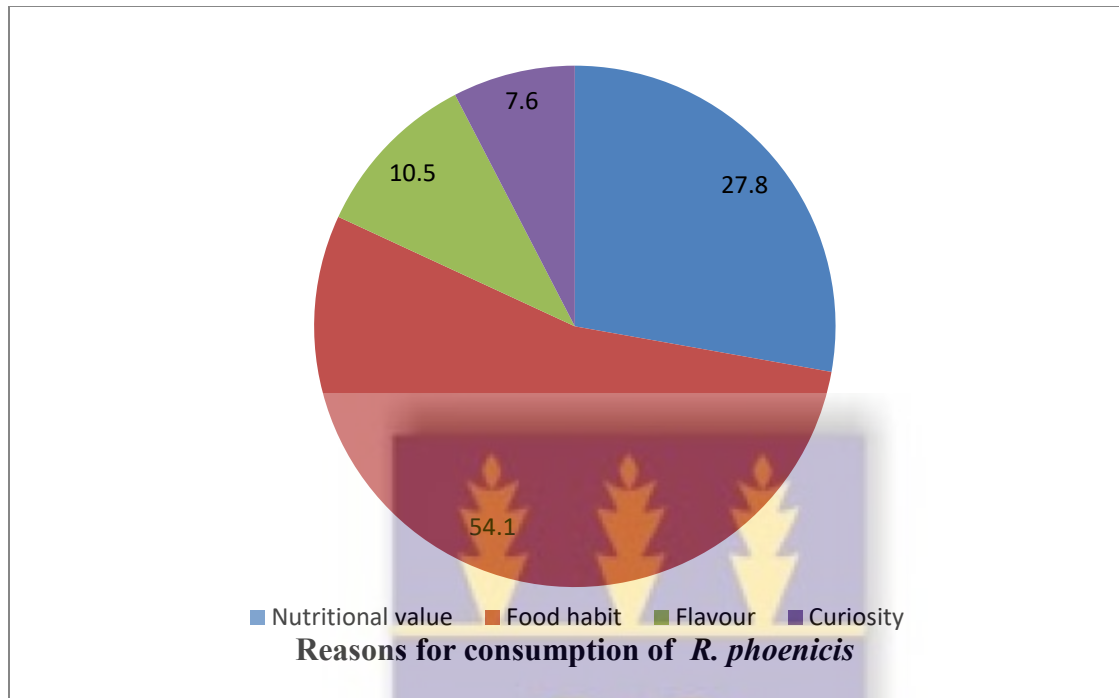


Figure 3: Pie chart showing different reasons for consumption of *R. phoenicis*.

R. phoenicis larva was consumed by all age groups as indicated by the respondents. From the 500 respondents interviewed, 92.4% (462) from all age groups actively consumed *R. phoenicis* larvae. 54.1% (270) of the individuals indicated that consumption of the *R. phoenicis* was a tradition (food habit) in Southern Ghana whilst 27.8% (139) indicated that, the larva was very nutritious and also good for the human body. The motivations for consumption of the palm weevil larva by other respondents were flavor (10.5%) (53) and curiosity (7.6%) (38) (Figure 3).

4.1.6 Preferred developmental stages of *R. phoenicis* consumed by respondents

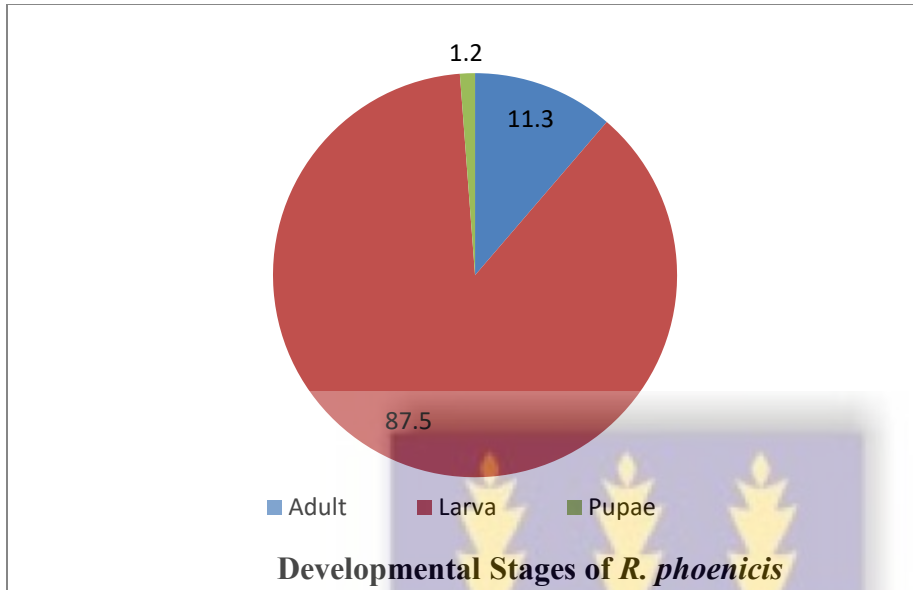
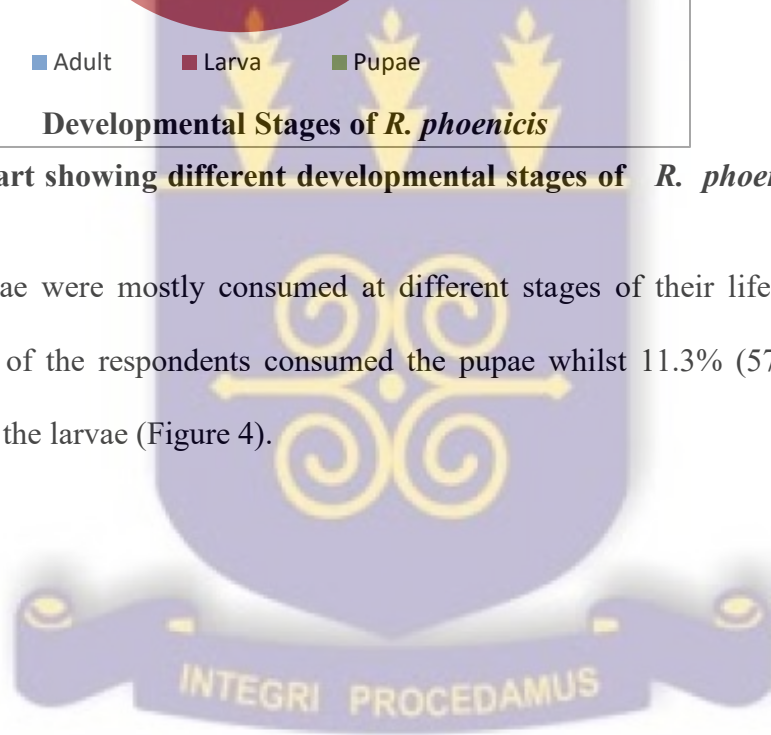


Figure 4: Pie chart showing different developmental stages of *R. phoenicis* consumed by respondents

R. phoenicis larvae were mostly consumed at different stages of their life cycle in Southern Ghana. 1.2% (6) of the respondents consumed the pupae whilst 11.3% (57) ate adult. 87.5% (437) fed on only the larvae (Figure 4).



4.1.7 Mode of Harvesting *R. phoenicis*

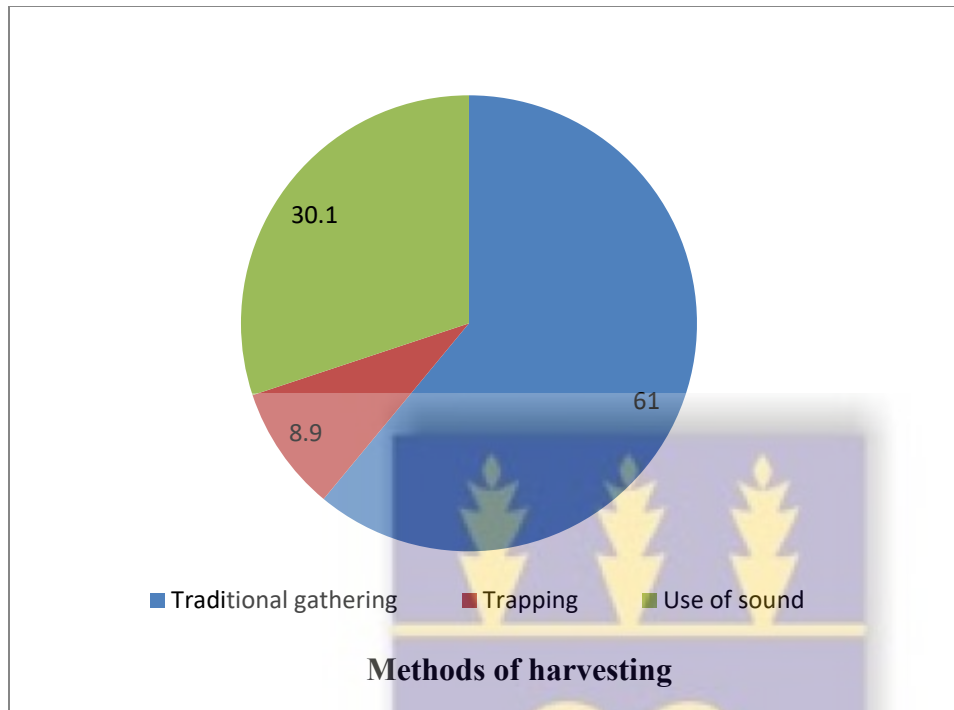


Figure 5: Pie chart showing different methods of harvesting *R. phoenicis*.

As shown in Figure 5, 61.0% (305) of the respondents collected the larvae by digging into the inner core of the dead palm tree after the palm wine tappers had tapped their wine from the felled palm tree whilst 30.1% (151) harvested the larvae by using the cryptic sound made by the larvae when feeding as a way of detecting their presence and 8.9% (44) harvested the adults by setting traps.

4.1.8 Mode of processing *R. phoenicis*

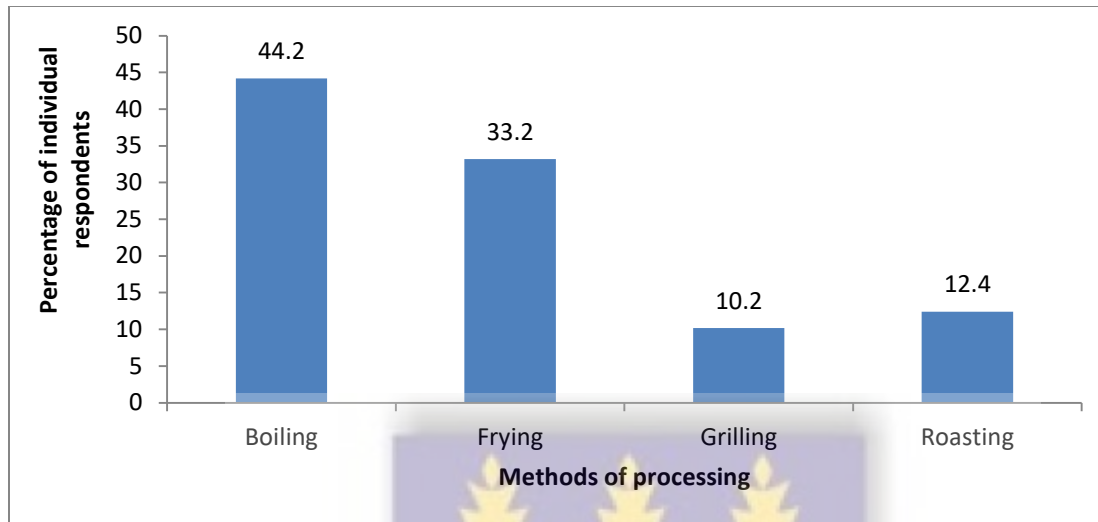


Figure 6: Bar chart showing different methods of processing *R. phoenicis*.

The *R. phoenicis* larvae were mostly prepared in different ways including boiling, frying, grilling and roasting (Figure 6). 44.2% (221) of the individual indicated that, the larvae were best eaten when boiled whilst 33.2% (166) and 10.2% (51) of the respondents preferred to eat fried and grilled larvae respectively. 12.4% (62) of the 500 respondents also preferred to roast the larva, pupae and the adult.



4.1.9 Methods of preserving *R. phoenicis*

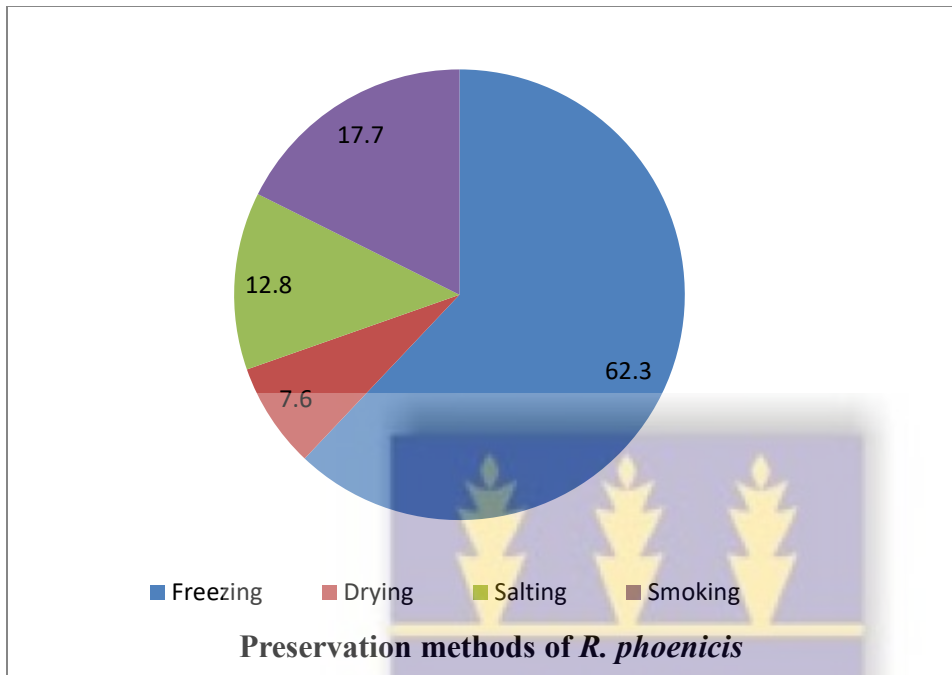


Figure 7: Pie graph showing different preservation methods of *R. phoenicis*.

Several preservation methods such as freezing, drying, salting and smoking were used by the respondents to increase the shelf life of the palm weevil larvae (Figure 7). 7.2% (36) of the individuals preserved their harvested or freshly purchased palm weevil larva, pupae and adult by drying whilst 12.8% (64) preferred salting. 62.3% (312) preferred to keep their larvae in a refrigerator whilst 17.7% (88) smoked the larvae to increase their shelf life.

4.2 LABORATORY EVALUATION OF SUBSTRATES FOR REARING *R. PHOENICIS*

4.2.1 Fecundity and hatchability of eggs

The statistical analysis indicated a significant difference ($P > 0.05$) in the number of eggs laid, hatchability and average of eggs per female adult on the different substrates (Tables 8, 9 and 10). Significantly more eggs and higher average eggs per female were recorded on palm heart under the experiment condition compared to the others substrates (Table 8). Percentage of eggs hatch were more pronounced on palm heart and raphia palm at $24 \pm 2^\circ\text{C}$, $70 \pm 5\% \text{R.H}$ (Table 8) and $28 \pm 2^\circ\text{C}$, $70 \pm 5\% \text{R.H}$ (Table 10) but was however low at $20 \pm 2^\circ\text{C}$, $70 \pm 5 \text{RH}$ (Table 9).

Table: 8 Effect of different substrates and temperature conditions on the developmental characteristics of *R. phoenicis* reared in the laboratory

24 ± 2°C, 70 ± 5%R.H (Mean ± SD)									
Treatment	Oviposition Period	Eggs laid	Eggs hatched	%Hatchability	Average number of eggs per adult	Larval Period	Pupation period	Adults emergence	Longevity
Sugarcane slice	5.00 ± 0.7b	85.2 ± 4.7a	77.8 ± 3.5a	91	28.40 ± 1.581a	29.40 ± 0.510b	34.4 ± 0.9b	15.4 ± 1.5a	68.8 ± 1.8b
Palm heart	5.8 ± 0.5c	122.6 ± 7.4a	117.2 ± 7.5a	95.9	40.8 ± 2.4a	20.0 ± 0.7a	27.8 ± 1.5a	14.6 ± 0.8b	53.4 ± 1.9a
Raphia palm	3.6 ± 0.2a	102.4 ± 2.9a	97.2 ± 3.41a	94.9	34.1 ± 0.9a	22.6 ± 0.7a	30.4 ± 1.0a	10.2 ± 0.6b	56.8 ± 1.4a
<i>P</i> value	0.043	0.001	0.001		0.001	0.000	0.009	0.008	0.000

Table 9: Effect of different substrates and temperature conditions on the developmental characteristics of *R. phoenicis* reared in the laboratory.

20 ± 2 °C, 70 ± 5%R.H. (Mean ± SD)									
Treatm ent	Ovipo sition Period	Eggs laid	Eggs hatched	%H atch ability	Average eggs number of per adult	Larval period	Pupatio n period	Adult emerge nce	Longev ity
Sugarca ne slice	5.8 ± 0.5c	57.0 ± 5.0a	37.0 ± 4.0a	65.9	19.0 ± 1.7 a	39.4 ± 0.5a	33.0 ± 0.8b	18.2 ± 0.6b	73.2 ± 0.9b
Palm heart	3.6 ± 0.2a	97.6 ± 8.8b	67.2 ± 2.6b	68.9	32.5 ± 2.9b	26.6 ± 0.7a	24.2 ± 0.6a	11.4 ± 0.5a	56.6 ± 1.3a
Raphia Palm	5.0 ± 0.7b	87.8 ± 6.9b	56.2 ± 4.6b	64	29.2 ± 2.3b	30.2 ± 0.3a	30.4 ± 1.0b	10.8 ± 1.1a	67.2 ± 0.7a
<i>P</i> value	0.043	0.004	0.000		0.004	0.040	0.000	0.000	0.000

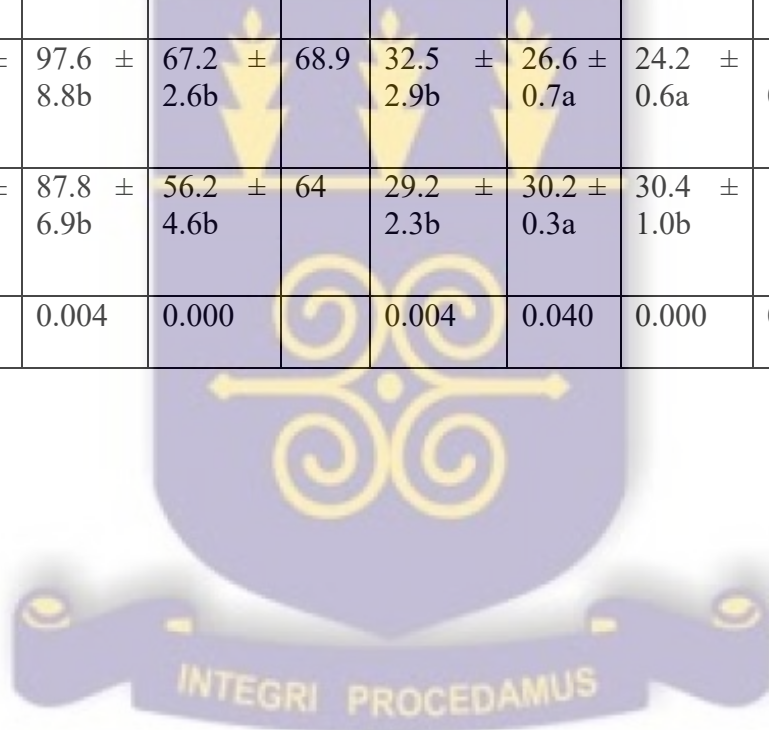


Table 10: Effect of different substrates and temperature conditions on the developmental characteristics of *R. phoenicis* reared in the laboratory

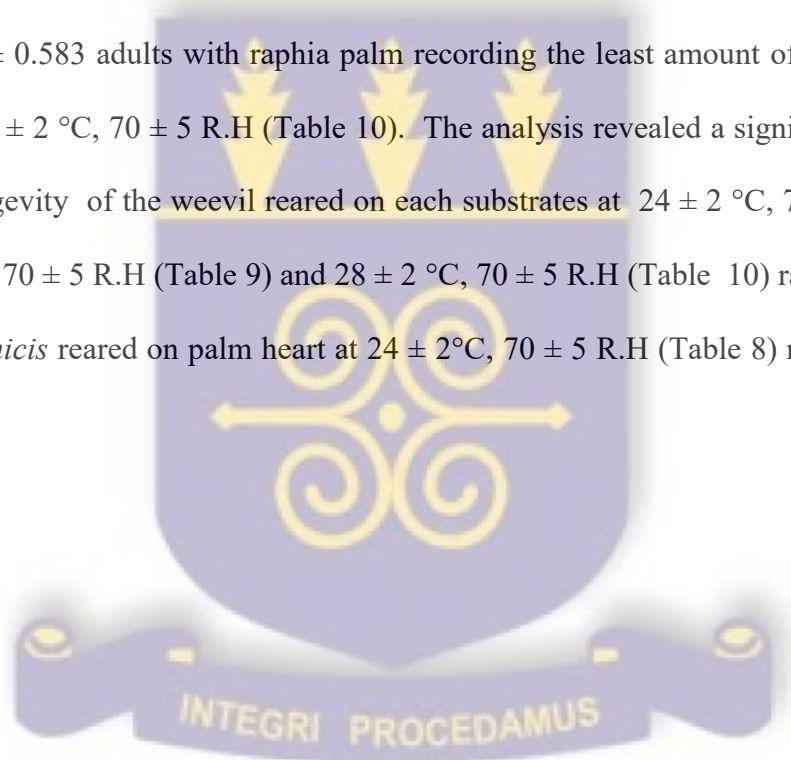
28 ± 2°C ,70 ± 5%R.H. (Mean ± SD)									
Treatm ent	Ovipo sition Period	Eggs laid	Eggs hatched	%Hatch ability	Average eggs per adult	Larval period	Pupation period	Adult Successful emergence	Longevity
Sugarcane slice	4.40 ± 0.5bc	77.8 ± 5.8a	71.8 ± 5.3a	92	25.9 ± 1.9a	33.8 ± 33.8b	40.4 ± 0.5a	10.6 ± 1.0a	78.6 ± 0.9b
Palm heart	2.8 ± 0.3a	113.5 ± 7.4b	110.8 ± 7.2b	97	37.8 ± 2.5b	21.0 ± 0.3a	40.4 ± 0.6a	13.6 ± 1.3a	65.2 ± 1.2a
Raphia palm	3.40 ± 0.5b	99.2 ± 3.2b	97.4 ± 4.3b	97	36.3 ± 3.2b	26.4 ± 1.1a	47.8 ± 2.1b	9.2 ± 1.0a	77.6 ± 2.6b
<i>P</i> value	0.090	0.003	0.001		0.014	0.000	0.002	0.052	0.000

Means in the same column followed by the same letter are not significantly different at the $P = 0.05$.

4.3 The developmental stages of *R. phoenicis*

The developmental stages of *R. phoenicis* were studied on slices of sugarcane, palm heart and raphia palm. Significant differences ($P < 0.05$) occurred in the duration of different stages of *R. phoenicis* at temperatures $24 \pm 2^\circ\text{C}$, 70 ± 5 RH (Table 8) and $20 \pm 2^\circ\text{C}$, $\pm 70 \pm 5$ RH (Table 9). However oviposition period and adult emergence of *R. phoenicis* were insignificant at $28 \pm 2^\circ\text{C}$, 70 ± 5 RH (Table 10), even though the number of egg laid, hatchability of eggs, larval period, pupation period, and longevity were significant. Oviposition started from 2.8 to 5.8 days after mating on the different substrates. The Oviposition period on the different substrates was significant ($P > 0.05$) at $24 \pm 2^\circ\text{C}$, 70 ± 5 R.H (Table 9) and $20 \pm 2^\circ\text{C}$, 70 ± 5 R.H (Table 9).

However, it was insignificant ($P < 0.05$) at 28 ± 2 °C, 70 ± 5 R.H (Table 10). The larval period on the various substrates differed significantly ($P > 0.05$). The pupation period presented in Table 7, 8 and 9 were significant. However there was also significant difference ($P < 0.05$) in the number of days the pupae spent on the three substrates at different temperatures. Statistically, adult emergence was highly significant at temperature 24 ± 2 °C, 70 ± 5 R.H (Table 8) and 20 ± 2 °C, 70 ± 5 R.H (Table 9), whilst it was insignificant at 28 ± 2 °C, 70 ± 5 R.H (Table 10). Sugarcane slices recorded the highest adult emergence at 20 ± 2 °C, 70 ± 5 R.H. (Table 9) recording 18.20 ± 0.583 adults with raphia palm recording the least amount of adult emergence (9.20 ± 1.0) at 28 ± 2 °C, 70 ± 5 R.H (Table 10). The analysis revealed a significant differences ($P > 0.05$) in longevity of the weevil reared on each substrates at 24 ± 2 °C, 70 ± 5 R.H (Table 7) and 20 ± 2 °C, 70 ± 5 R.H (Table 9) and 28 ± 2 °C, 70 ± 5 R.H (Table 10) ranging from 53 to 78 days. *R. phoenicis* reared on palm heart at 24 ± 2 °C, 70 ± 5 R.H (Table 8) resulted in shorter longevity.



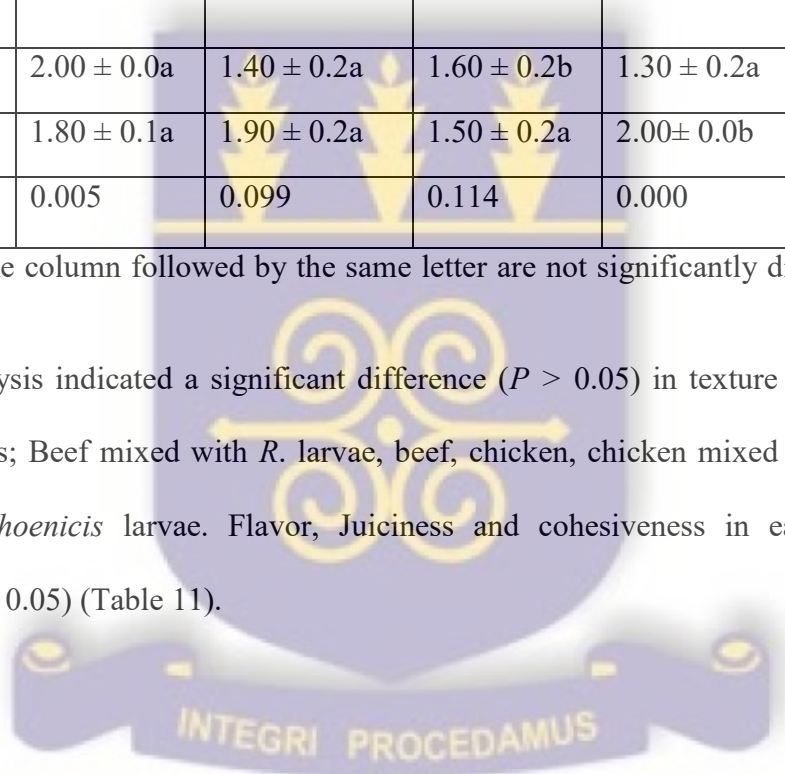
4.5 SENSORY EVALUATION OF SAMPLES

Table 11: Sensory characteristics of the samples

Treatments	Texture	Flavour	Juiciness	Colour	Cohesiveness
Beef mixed with <i>R. phoenicis</i> larvae	1.40 ± 0.2a	2.10 ± 0.1a	1.70 ± 0.2b	2.10 ± 0.1b	1.60 ± 0.2a
Beef	1.40 ± 0.16a	2.00 ± 0.2a	1.90 ± 0.2b	1.10 ± 0.1a	1.80 ± 0.2c
Chicken mixed with <i>R. larvae</i>	2.10 ± 2.3b	1.8 0± 0.2a	2.20 ± 0.2b	2..50 ± 0.2c	1.60 ± 0.2b
Chicken	2.00 ± 0.0a	1.40 ± 0.2a	1.60 ± 0.2b	1.30 ± 0.2a	1.80 ± 0.2d
<i>R. larvae</i>	1.80 ± 0.1a	1.90 ± 0.2a	1.50 ± 0.2a	2.00± 0.0b	2.00 ± 0.2d
<i>P</i> value	0.005	0.099	0.114	0.000	0.596

Means in the same column followed by the same letter are not significantly different at the $P = 0.05$

The sensory analysis indicated a significant difference ($P > 0.05$) in texture and colour of the following samples; Beef mixed with *R. larvae*, beef, chicken, chicken mixed with *R. phoenicis* larvae and *R. phoenicis* larvae. Flavor, Juiciness and cohesiveness in each sample were insignificant ($P < 0.05$) (Table 11).



4.5.1 Acceptability of *R. phoenicis* larvae

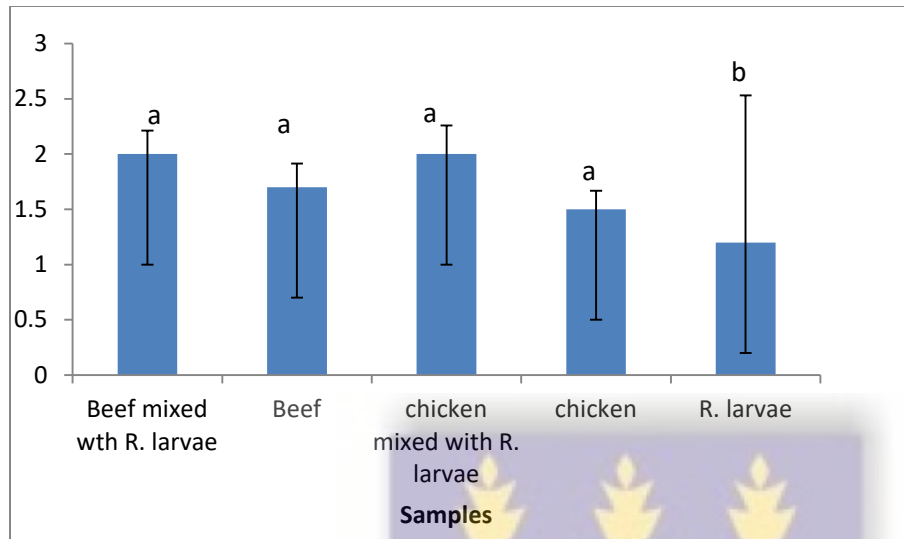
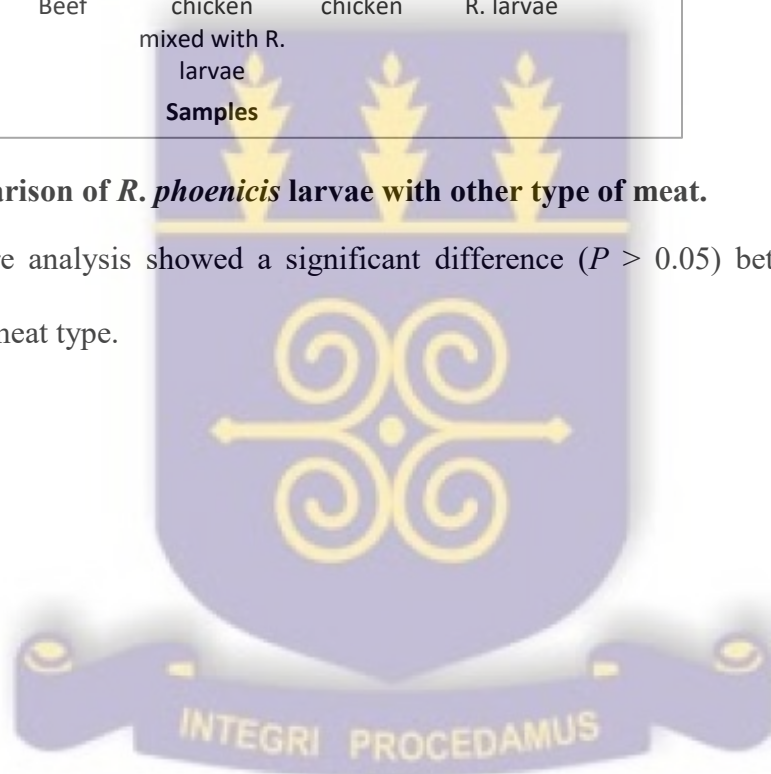


Figure: 8 Comparison of *R. phoenicis* larvae with other type of meat.

The sensory score analysis showed a significant difference ($P > 0.05$) between *R. phoenicis* larvae and other meat type.



CHAPTER FIVE

5.0 DISCUSSION

5.1 PRELIMINARY SURVEY ON TRADITIONAL KNOWLEDGE OF CONSUMPTION OF *R. PHOENICIS*

5.1.1 Perception about consumption of *R. phoenicis*

R. phoenicis is consumed by the Akans and has the potential to reduce food insecurity in Southern Ghana though there is the needs to disabuse people's minds of certain negative impressions current generation have about entomophagy of this insect. Different stages of *R. phoenicis* were consumed in the three districts base on their distribution and factors that affected their seasonality, although the daily use of *R. phoenicis* was limited by their availability and high perishable nature. Identifying appropriate substrates for mass rearing of *R. phoenicis* and processing them with an acceptable or conventional cooking method could increase their shelf life and also promote entomophagy and commercialization of this insect in Southern Ghana. Besides being an important component of the diet many people in the region, respondents indicated that *R. phoenicis* has a commercial and medicinal value with higher potential of combating illness such as anemia among pregnant woman in the area. The traditional use of this insect as food continues to be widespread among the youth as it provides significant nutritional, economic, and ecological benefits for rural communities. 92.4% (462) of the respondents from all age groups actively eat the insect as part of their diet, particularly in Brim South. Elsewhere in Kenya where malnutrition is prevalent, studies have shown that wheat buns enriched with *R. phoenicis* are actually preferred by the locals over ordinary bread (Gahukar, 2011) as they provide a significant nutritional contribution, especially during times of drought and famine (Gahukar, 2011).

5.1.2 Seasonal availability of *R. phoenicis*

50.2% (251) of the respondents indicated that, the *R. phoenicis* larvae were mostly abundant during the rainy season because of easy access and of food during this period. According to Aman et al. (2000) *R. ferrugineus* adults were mostly harvested from early May to late November with three peaks in the middle of June, late July, and early September. However, 10.6% (53) of the respondents indicated that, *R. phoenicis* larvae could be found at the onset of the dry season (Fig. 2). According to Alpizar et al. (2002), the survival rate of *Metamasius hemipterus* (Coleopteran: Curculionidae) in the dry season was high due to the declined action of bacteria and fungi on the cocoon. Furthermore, 39.2% (196) stated that, the weevil could be found all year round due to the frequent changes in the weather. This was in agreement with Kyerematen et al. (2014), who said the high abundance of insect species in forest plantation was probably due to the availability of abundant food sources for the insects.

5.1.3 Harvesting of *R. phoenicis*

Harvesting of the larvae was very difficult due to the burrowing nature of the insect. 61% (305) of respondents gathered the larvae by digging the inner core of the dead palm trees after the palm wine tappers have tapped their wine from the palm tree. Muafor *et al.* (2015) revealed that, in areas like Abong-Mbang and Mbalmayo in Cameroon, the larvae were systematically harvested from the wild by splitting an infested raphia palm tree and extracting them from it with the hand. 8.9% (44) of respondents in this study used trapping as a means of harvesting the adults whilst 30.1% (151) used the sounds produced by the insect the presence of the larvae in its ecosystem (Figure 3). The larvae make a cryptic sound when feeding. According to Muafor *et al.* (2015) collectors of African palm weevil larva carefully listened to the sound and vibration produced by feeding grub. This method was very popular in some villages in the Southern parts of Cameroun

as collectors in areas like Ntoun and Abong-Mbang saw it as an efficient way of detecting and harvesting the larvae (Dounias, 1999).

5.1.4 Reasons for consumption of *R. phoenicis*

R. phoenicis larvae were a popular delicacy among the Akans and it was consumed by all age groups as indicated by the respondents. From 500 respondents interviewed, 92.5% (462) who actively consumed the larvae were from all age groups. According to 54.1% (270) of the respondents, consumption of the larvae is a tradition (food habit) in all the three districts in Southern Ghana (Figure. 4). This figure is higher than what was reported by Niaba et al. (2012), who stated that 25.7% of respondents consumed termites as a tradition in Cote d'Ivoire. Furthermore, 27.8% (139) of the respondents indicated that, the larva was very nutritious and also good for the human body. Adeoye *et al.*(2014) however reported that,10-15% of the respondents' interviewed in Itokin and Epe respectively in Nigeria, especially the overweight and diabetic patients used *R. phoenicis* in their diet as it has the potential of maintaining weight and treating diabetic patients. 10.5% (53) of the respondents' source of motivation for consumption of the palm weevil larva was its flavor whilst 7.6% (38) consumed it out of curiosity. These figures were lower than what was reported by Niaba et al. (2012) who reported that 17.7% of the respondents consumed winged termites out of curiosity as against 42.2% who consumed the winged termites because of flavour.

5.1.5 Processing of *R. phoenicis*

The palm weevil larva was prepared in different ways including boiling, frying, grilling and roasting. 44.2% (221) of the individual indicated that, the larvae were best eaten when boiled whilst 33.2% (166) of the respondents prefer to eat fried larvae (Figure. 5). De Foliart (1993) confirmed that, in some localities in Africa, the larvae were pierced in the abdomen with a sharp

stick and washed in water to drain off the white fatty liquid from their body before they were boiled or fried in vegetable oil for consumption. 10.2% (51) – 12.4% (64) of the respondents in this study also preferred to roast and grill *R. phoenicis* respectively for consumption. According to Ogbuagu *et al.* (2011) raphia palm larvae were mostly roasted, grilled and garnished with spices and consumed with palm wine while others also replaced meat with roasted larvae when taking rice in Nigeria.

5.1.6 Preservation of *R. phoenicis*

Several methods of preservation such as freezing, drying, salting and smoking were used by the respondents to increase the shelf life of the palm weevil larvae (Figure 7). 7.2% (36) of the respondents preserved their harvested or freshly purchased palm weevil larvae or adults by drying whilst 12.4% (64) preferred salting. According to Adeoye *et al.* (2014) 50-52% of the respondents in Itokin and Epe in Nigeria preserved freshly harvested insects by drying and salting respectively. In this survey, 62.3% (312) preferred to keep their larvae in a refrigerator whilst 17.7% (88) rather smoked the larvae to increase their shelf life. These values were also above those obtained by Adeoye *et al.* (2014) in Itokin and Epe in Nigeria where 5% of the respondents preserved their insects in a refrigerator whilst 6% rather preferred to smoke the insects.

5.2 LABORATORY EVALUATION OF SUBSTRATES

5.2.1 Fecundity and hatchability of eggs

The egg laying period of *R. phoenicis* at the different temperatures lasted between 3 - 5.8 days after mating. A decline in oviposition period was observed on sugarcane slices at the different temperatures after one week. This continued until all the females died (Table 10). Slices of Sugarcane lost its nutrients and moisture due to a higher temperature which caused early mortalities in female adults after a week and this explains why the least number of eggs were laid. Hopkins and Ekbohm (1999) observed that oviposition continues in Coleopteran species until they die. The oviposition period of females reared on the various substrates at different temperatures ranged from 2.8 to 5.8 days on palm heart, 4.40 to 5.80 days on slices of Sugarcane and 3.4 to 5.0 days on raphia palm. The period observed on palm heart in this study at 28 ± 2 °C, $70 \pm 5\%$ R.H was considerably below the 3.8 days reported by Kaakeh (2005) and far below 36 days reported by Monzenga *et al.* (2015) on slices of Sugarcane and slightly below 6.1 days reported by Anonymous (2015) under the same environmental conditions. The egg laying efficiency and percentage hatchability varied at different temperatures; palm heart recording the highest amount of eggs laid (122.60 ± 7.4) and hatchability (117 ± 7.5) at 24 ± 2 °C, $70 \pm 5\%$ R.H (Table 8) compared to 20 ± 2 °C, $70 \pm 5\%$ R.H. (Table 9) and 28 ± 2 °C, $70 \pm 5\%$ R.H. (Table 10). Substrates at 20 ± 2 °C, $70 \pm 5\%$ R.H recorded the lowest eggs laid and hatchability. However, percentage hatchability of eggs observed on slices of Sugarcane and palm heart were above the 74.3%, and 93.3% obtained by Kaakeh (2005) and 90% by Anonymous (2015) on raphia palm at 24 ± 2 °C, $70 \pm 5\%$ R.H (Table 8). The observed variation in number of eggs on Sugarcane slices and raphia palm at 24 ± 2 °C, $70 \pm 5\%$ R.H decreased due to their inability to retain water and nutrients for a longer period which adversely affected feeding, mating and egg laying of female adults. This was contrary to report by both El-Ezaby, (1997) and Monzenga *et*

al., (2015), Sugarcane slices, there appears to be the best substrates for egg laying in *R. phoenicis*.

5.2.2 Developmental stages of *R. phoenicis*

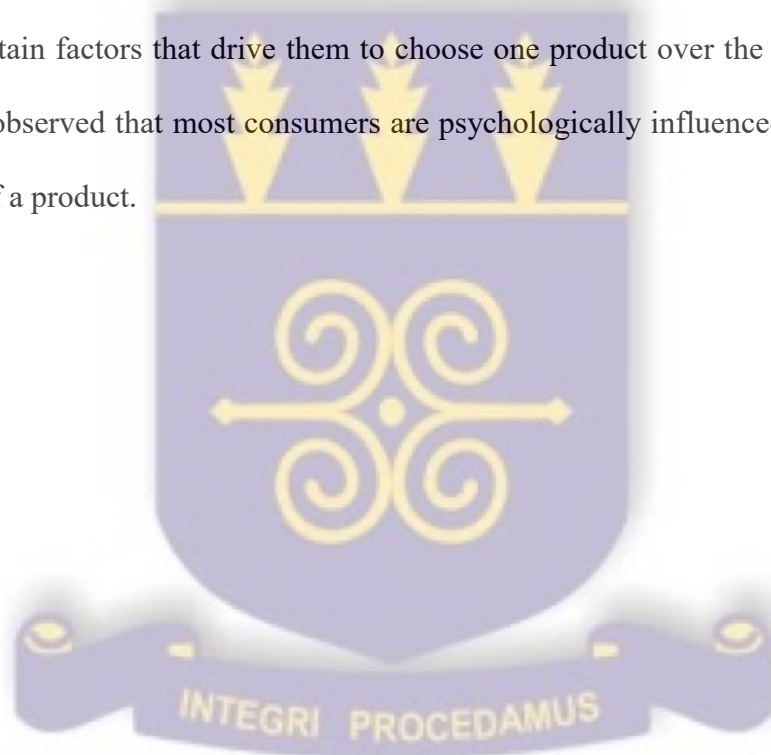
The larval duration showed a significant difference ($P > 0.05$) on each substrate at the different test temperatures. A shorter larval period was observed on palm heart (20.0 ± 0.7 days) at 24 ± 2 °C, $70 \pm 5\%$ R.H (Table 8) compared to what was observed on the same substrate at other temperatures. The variation in larval development on the same substrate at the different temperatures could be attributed to the substrate losing its nutritive value. Leather (1990) reported that nutritional content of the host plant positively affect larval development. This result confirmed the larval duration reported by Monzenga *et al.* (2015) on sugarcane slices. However, the value obtained on palm heart at 24 ± 2 °C, $70 \pm 5\%$ R.H (Table 8) was higher than the 21- 25 days earlier reported by Monzenga *et al.* (2015) and below 33 days obtained by Anonymous (2015). An increase in larval period by Anonymous (2015) could have been caused by suboptimal conditions on palm heart. The result showed a higher longevity of *R. phoenicis* in pupation on slices of raphia palm at 28 ± 2 °C, $70 \pm 5\%$ R.H (Table 10). However pupation on palm heart was lower at 24 ± 2 °C, $70 \pm 5\%$ R.H (Table 8). This variation in pupation period explains why higher temperature reduces the moisture contents of the feed which does not enhance feeding; hence larvae are false to pupate under such condition. The pupation period observed in the present studies on slices of sugarcane was below 38.5 - 41 days as reported by Bong *et al.*(2008) and above 21 days by Kaakeh (2005) on palm heart and considerably lower than 38 days reported by Anonymous (2015) on raphia palm. Slices of Sugarcane significantly proved to be the suitable substrate for pupation as it recorded the highest successful adult emergence compared at 20 ± 2 °C, $70 \pm 5\%$ R.H. This is in agreement with Kakeeh *et al.* (2001)

who reported that sugarcane stem was the best substrate for pupation in *R. phoenicis*. The longevity period of *R. phoenicis* was significant ($P > 0.05$) at 24 ± 2 °C, $70 \pm 5\%$ R.H. with palm heart positively affecting the growth and development of *R. phoenicis* compared to slices of Sugarcane and raphia palm (Table 8). Dembilio and Jacas (2011) reported that, temperature has significant effect on the longevity of the red palm weevil *Rynchophorus ferrugineus* Olivier (Coleoptera: Curculionidae) on both artificial and natural diets. Palm heart recorded the shortest longevity period of 53.40 ± 1.9 days compared to 56.80 ± 1.4 and 68.80 ± 1.8 days observed on raphia palm and sugarcane slices respectively. This observed period on sugarcane slices was below the 73 days reported by Monzenga *et al.* (2015). The longevity period observed in the present study was shorter than 124.4 days obtained on palm heart, using *R. ferrugineus* (Kaakeh, 2005). However it was below 70 days as reported by Anonymous (2015) on raphia palm.

5.3 SENSORY EVALUATION OF THE SAMPLES

The incorporation of *R. phoenicis* larvae in beef and chicken significantly affected the sensory scores of colour and texture of the sausage. The sensory characteristics indicated by the panelist provided a deeper understanding of the quality of *R. phoenicis* in each sample. Watt *et al.* (1989) confirmed that certain food characteristics such as flavour, texture, juiciness and colour positively affect the quality of product. Feiner (2006) suggested that, colour is one important criterion most consumers look out for when purchasing a particular product. There was a significant difference ($P < 0.05$) between the means of juiciness of *R. phoenicis* larvae and the other meat products. This could be attributed to the fact the *R. phoenicis* larvae contain excess fat as consumers mostly fried them in oil that comes from the larvae. Huis *et al.* (2013) reported that, edible insects are a considerable source of fat and Ogbuagu *et al.* (2011) investigated the fatty acid composition of Raphia palm weevil. The result revealed two fatty acid composition;

Palmitoleic acid (30.28%) and Stearic acid (69.72%) which does not pose any health implication (McLeod and Ames, 1988). Compatibility of the samples was insignificant ($P > 0.05$). The heating of the samples released a gel-like liquid which binds them together. Acton and Dick (1989) confirmed that thermal processing produces a gel-like liquid which binds the samples together. Acceptability of the samples differed significantly ($P < 0.05$). However, the panelists showed more preference for *R. phoenicis* larvae sausage to the other sausages, indicating the quality of the *R. phoenicis* larvae. Consumers' behaviour in selection of product is mostly influenced by certain factors that drive them to choose one product over the other. Axelson and Brinberg (1989) observed that most consumers are psychologically influenced towards selection and purchasing of a product.



CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATION

6.1 CONCLUSIONS

The studies have revealed that most females (56.8%) (282) in Southern Ghana consumed *R. phoenicis* than males (43.6%) (218). However 92.4% (462) of the respondents actively consumed *R. phoenicis* whilst 8.3% (42) indicated that entomophagy was primitive. The survey however showed that, Birim South (38.7%) (194) was the major *R. phoenicis* consumption area followed by East Akim (32.4%) (162) and Kwahu West (28.4%) (144).

The laboratory studies showed that, palm heart recorded the highest number of eggs laid (122.60 ± 7.487) and percentage hatchability of 95.5% compared to the other substrates at $24 \pm 2^\circ\text{C}$, 70 ± 5 with larval period and longevity of *R. phoenicis* being shorter (Table 8). Slices of Sugarcane were the most suitable substrate for pupation recording the highest adult emergence (18.20 ± 0.583) at $20 \pm 2^\circ\text{C}$, 70 ± 5 (Table 9) compared to the other substrates at the various temperatures. However, the life cycle of *R. phoenicis* was shorter at $24 \pm 2^\circ\text{C}$, 70 ± 5 on palm heart compared to the other substrates at different temperatures.

The sensory evaluation scores indicated a higher preference for *R. phoenicis* larva sausage, compared to the other samples by the panelist, showing its potential as a business venture among the average Ghanaian in Southern Ghana.

In general, *R. phoenicis* was consumed by Akans and has the potential to reduce food insecurity in Southern Ghana though there was the need to disabuse people's minds of the negative impressions they have about entomophagy. Processing of the larvae into sausage could lure the 8.3% of the respondents who saw its consumption as primitive to accept it as a delicacy. Palm heart was the most suitable substrate for rearing *R. phoenicis* because it provided a higher

number of hatchability, and also offered shortest larval period and longevity period of the weevil at $24 \pm 2^\circ\text{C}$, 70 ± 5 . However, slices of Sugarcane were the most suitable pupation material for rearing *R. phoenicis* at $20 \pm 2^\circ\text{C}$, 70 ± 5 R.H.

6.2 Recommendation

There should be practical research into mass rearing of *R. phoenicis* with affordable technologies on other substrates and these technologies should be transferred to insect farmers, with intensive supervision by extension officers, and this will go a long way to ensure food security in Southern Ghana.



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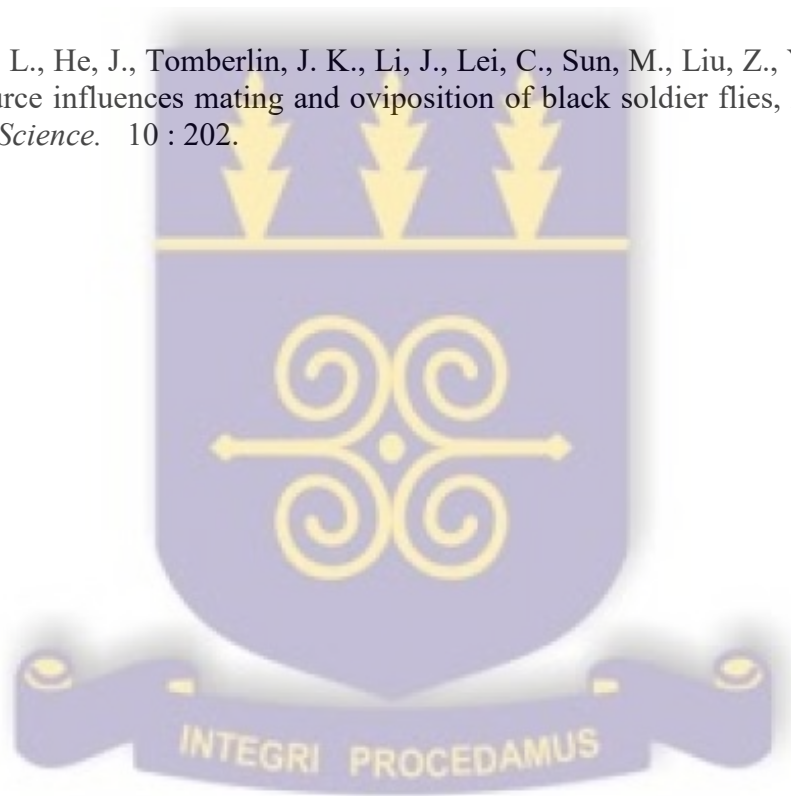
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APPENDIX 1: QUESTIONNAIRE USED

a. Age:

- 1) 18 - 29 2) 30 - 39 3) 40-60

b. Gender

1. M 2. F

c. Educational level

1. Tertiary 2. Senior high school 3. Primary school
4. Others.....

d. District.....

e. Do you eat palm weevil larvae?

1. Yes 2. No

f. What is the common name?

.....
INTEGRI PROCEDAMUS

g. Reason for consumption of this insect

1. Nutritional value 2. Food habit 3. flavor 4 curiosity

h. At what stage do you eat this insect?

.....

i. Where do you get this insect?

1. Wild 2. Market

j. Which seasons are you likely to get this insect?

1. Rainy season 2. Dry season 3. All year round

k. Which methods is use in harvesting this insect

1. Trapping 2. Handpicking 3. Other.....

l. How do you process it for consumption?

1. Boiling 2. Frying 3. Grilling 4. Roasting

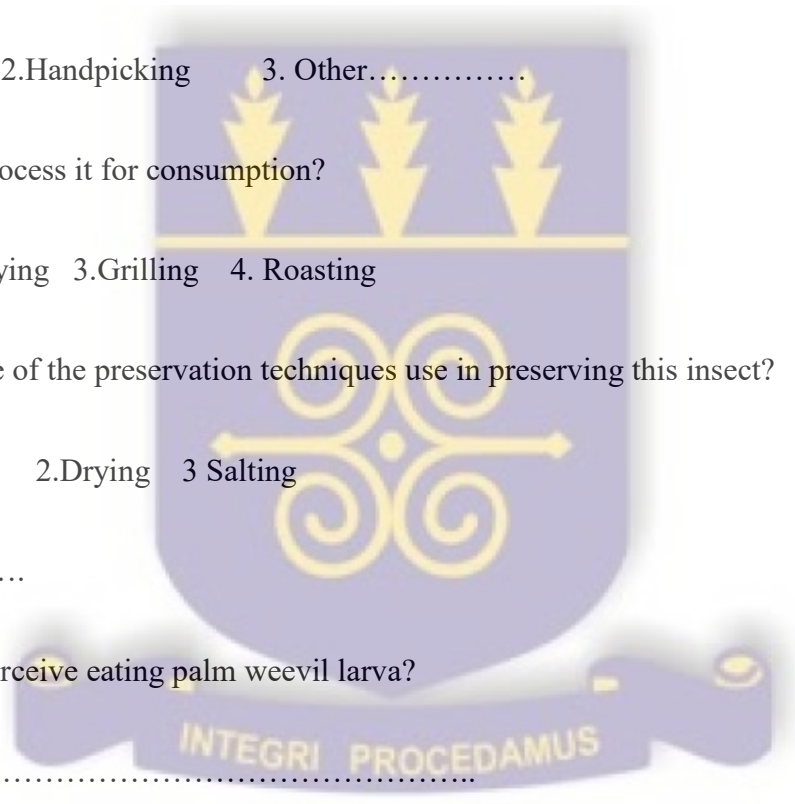
m. What are some of the preservation techniques use in preserving this insect?

1. Freezing 2. Drying 3. Salting

Others.....

n. How do you perceive eating palm weevil larva?

.....



Appendix 2: Effect of different substrates and temperature conditions on the developmental characteristics of *R. phoenicis* reared in the laboratory; ($24 \pm 2^\circ\text{C}$, $70 \pm 5\%$.)

Parameter	Df	mean square	F	sig
Oviposition	2	6.200	4.133	0.043
egg laid	2	1752.200	12.062	0.001
egg hatch	2	1940.600	14.144	0.001
average egg laid	2	194.560	12.069	0.001
larval period	2	117.800	53.545	0.000
pupal period	2	55.267	7.272	0.009
successful adult emergence	2	39.200	7.443	0.008
longevity span	2	327.267	21.484	0.000

Appendix 3: Effect of different substrates and temperature conditions on the developmental characteristics of *R. phoenicis* reared in the laboratory ; ($20 \pm 2^\circ\text{C}$, $70 \pm 5\% \text{R.H.}$)

Parameter	Df	Mean square	F	sig
Oviposition	2	6.200	4.133	0.043
Egg laid	2	2244.200	8.865	0.004
Egg hatch	2	1168.067	15.899	0.000
Average egg laid	2	249.343	8.866	0.004
Larval period	2	28.867	20.140	0.000
Pupal period	2	102.200	27.873	0.000
Successful adult emergence	2	84.467	29.126	0.000
Longevity span	2	353.267	67.503	0.000

Appendix 4: Effect of different substrates and temperature conditions on the developmental characteristics of *R. phoenicis* reared in the laboratory ($28 \pm 2^\circ\text{C}$, $70 \pm 5\% \text{R.H.}$)

Parameter	df	Mean square	F	sig
Oviposition	2	3.267	2.970	0.090
Egg laid	2	1605.800	9.670	0.003
Egg hatch	2	1963.267	12.064	0.001
Average egg laid	2	208.651	6.167	0.014
Larval period	2	206.467	51.617	0.000
Pupal period	2	91.267	11.040	0.002
Successful adult emergence	2	25.267	3.828	0.052
Longevity span	2	278.600	18.450	0.000

Appendix 4: Sensory evaluations of samples

Sensory Characteristics	df	Mean square	F	sig
Texture	4	1.080	4.301	0.005
Flavour	4	0.730	2.079	0.099
Juiciness	4	0.770	1.980	0.114
Colour	4	3.400	23.906	0.000
Cohesiveness	4	0.280	0.700	0.596
Acceptability	4	1.170	2.893	0.033