COCKROACHES AS HOUSE HOLD PESTS

By:

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DEDICATION

To my parents, brothers and sisters to all those who stood beside me and whose love made this work possible.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABSTRACT

A laboratory study was carried out to investigate the hygienic importance of three cockroach species in the Sudan (*Blattela germanica*, *Blatta orientalis* and *Periplaneta americana*) as mechanical transmitters of pathogenic bacteria. This was followed by controled experiments using insecticides (propoxur and malathion), chemical compounds (sodium fluoride and boric acid) and natural plant products (usher leaves and whole fruits) with the aim of finding effective, environmentally safe methods of control.

Standard bacteriological methods were used to isolate and identify pathogenic bacteria carried by cockroaches.

Baits composed of sugar and starch containing insecticidal components was employed in the experiments. Palatability and mortality values were statistically analyzed and expressed as LD_{50} and LD_{95} (the concentration of the test that killed 50% and 95% of the exposed adults after 24 hours, respectively).

The study showed that cockroaches transmit several pathogenic bacteria. Although insecticides were more toxic than chemical compounds and the latters were more toxic than natural plant products, the study recommends the use of natural plant products for control because of environmental, economical and practical reasons.

الخلاصـــة

تتعلق الدراسة الحالية بالتحري عن البكتريا الممرضة التي تحملها ثلاثة أنـواع مـن الصراصير في السودان (بلاتيلا جيرمانيكا وبلاتا اوريتناليس وبيربيلانيتـا أميركانـا). كمـا تتضمن مكافحة الصراصير باستخدام مبيدات حشرية (بروبوكسر وملاثيون) ومواد كيميائيـة (فلوريد الصوديوم وحمض البوريك) ومواد نباتية (أوراق وثمرة العشر).

استخدمت طرق البحث القياسية لعزل البكتريا والتعرف على الأنواع الممرضة وقد تم استخدام الطعوم والمواد التي تحتوي على مبيدات ومواد كيميائية ومواد نباتية طبيعية.

تم تحليل درجة الاستساغة ومعدلات الموت إحصائيا وتم التعبير عنها بتحديد الجرعة المميتة لـ 50% من العدد الكلي والجرعة المميتة لـ 95% لكل جزء.

أوضحت الدراسة دور الصراصير في نقل العديد من أنواع البكتريا الممرضة. بالرغم من أن المبيدات الحشرية ذات سمية أعلى مقارنة بالمواد الكيميائية التي بدورها أعلى سـمية من المواد النباتية الطبيعية إلا أن الدراسة الحالية توصي باستخدام المواد النباتيـة الطبيعيـة للأسباب العملية والاقتصادية والبيئية.

CHAPTER ONE

INTRODUCTION

Cockroaches are very primitive insects. Their ancestors lived 200-350 million years ago in the Carboniferous Period, even before the dinosaurs. This geological period is sometimes called the "Age of Cockroaches" because they were so abundant. At this time, the climate on the earth was warm and moist, ideal conditions for them to thrive. Although climatic conditions are cooler and less humid now, present day cockroach species are surprisingly similar to those preserved in fossil from the distant past (James & Harwood, 1969).

These insects, are medium or large-sized insects belonging to the sub-order: Blattaria of order, Dictyoptera. This sub-order comprises about 4000 species. The medical importance of cockroaches is very likely much greater than generally realized. They have been shown to harbour pathogenic bacteria, serve as intermediate hosts for pathogenic helminthes, and to carry helminthes eggs, viruses, protozoa and fungi affecting man and other vertebrate animals (Roth & Willis, 1957; Roth &Willis, 1960; Tarshis, 1962; Cornwell, 1968; James & Harwood, 1969; Rueger &Olson, 1969; Pul'ver & Savchenko; 1973, Klowden & Greenberg, 1976, 1977; Cornwell & Mendes, 1981). Their habit of feeding on both human faeces and human food is an example of their potential health hazard to man. The importance of this point becomes clear when it is realized that cockroaches move freely from building to building and that the order in which these movements occur has no relationship to human sensibilities or public health considerations (Haines & Palmer, 1955).

Nevertheless, it has been difficult to prove a direct involvement of cockroaches in disease transmission (Burgess & Chetwyn, 1981). It is obvious that they can harbour and mechanically transmit disease-producing organisms.

They are present in situations, such as hospitals, where their involvement in disease transmission is highly probable. The problem arises in proving unequivocally that cockroaches are the vector in cases where other vectors and other means of disease transmission occur simultaneously. The nocturnal habits of the cockroach species is another complicating factor in obtaining such proof, because evens their presence may go undetected during a particular disease transmission episode.

Cases of ill-effects due to body contact between man and cockroaches are well established. Dermatitis of the skin and oedema of the eyelids have been attributed to cockroaches (Roth &Willis, 1957). Allergic reactions to cockroaches have also been described as occurring frequently, especially among certain groups of people (Cornwell, 1968).

Cockroaches may attempt to enter homes or other buildings from out-of-door habitat in cold weather, or they may move from adjoining homes or apartments. To prevent this from happening it is necessary to close all openings through floors, walls, doorframes, space behind baseboards, etc, that would permit their passage. Special attention should be given to water and steam pipes or other similar utility service lines. Carpentry work may be necessary if the openings are large; but putty, plastic, wood or other filler are usually satisfactory for smaller openings (Moore, 1973). Thoroughness in accomplishing this task must be emphasized because cockroaches can pass through very small spaces.

The importance of cleanliness, minimizing cockroach harbourages, and preventing their entry into homes and other building can not be overemphasized. Fulfillment of these requirements may make direct

control measures unnecessary; if not, they certainly make it more feasible to control cockroaches successfully with chemical insecticides.

Real success in the long-term prevention of cockroach infestations in buildings to be inhabited by man or animals depends largely on suppression or elimination of reservoir populations. It is well known that cockroaches often find desirable breeding sites in refuse dumps, sewer systems, sewage treatment plants, warehouses, ships, or other locations where food or suitable organic matter is available (Cornwell, 1968). It is not unusual for tremendous populations to develop in situations of this kind, particularly in warmer areas of the world. Cockroaches can live and reproduce outdoors throughout the year, and even in temperate climates there are many situations in which adequate heat and shelter are provided to sustain breeding with little interruption. It should be evident that any long-term plan to eliminate cockroaches from homes, apartments, and other buildings, will be a very difficult task unless reservoir populations in the area are greatly suppressed.

Study Motivation and Objective:

The most domesticated species of cockroaches readily feed both on human faeces and human food. This is an example of their potential hazard to man. The importance of this point becomes clear when it is realized that cockroaches move freely from building to building or from sewer to human habitations (Haines & Palmer, 1955).

Cockroaches are abundant in almost every part of the Sudan. Poor sanitary conditions prevail in most of the dwelling areas. The majority of the inhabitants live in rural areas. Only a very small percent of the urban population have access to proper water carriage system of disposal. The majority of urban populations use pit latrines of some kind. Many citizens are not aware of the potential health hazard of these insects.

Moreover, kitchens-where cockroaches move to during their nocturnal activity- are not equipped with appropriate insect-proof doors and cupboards. Remains of foodstuff in such kitchens attract these insects.

Several insecticides were applied successfully to control cockroaches. The successive application of chemical control leads to the following problems: resistance of cockroaches to insecticides, hazardous effects on the surrounding environment and the population living around, chemicals kill both target and non-target organisms and most chemicals are very expensive and beyond the financial capacities of the developing countries.

One objective of this study is to evaluate, on scientific basis, the hygienic importance of cockroach species in the Sudan. Another objective is to find out low-risk, practical and economical means of control.

CHAPTER TWO
LITERATURE REVIEW

2.1 Cockroaches of Sanitary Importance:

2.1.1. The German cockroaches *Blattela germanica* (Linnaeus):

2.1.1.1 Distribution:

If any species of cockroaches can be spoken of as being cosmopolitan, it is this one, as it is found in virtually all parts of the world (Princis, 1969). This species originated in Northeast Africa in the vicinity of the Great African Lakes and what is now Ethiopia (Rehn, 1945). Its early spread from that area into Eastern Europe and Asia Minor has been reasonably well documented. It is believed to have been introduced into the New World from Europe rather than from Africa. As its origin indicates, it is present, but not often abundant, in the tropics (Asahina & Hasegawa, 1981), and has penetrated well into northern and southern temperate climates. This is truly a remarkable insect species in many ways, not the least of, which is its ability to thrive virtually wherever man has taken it. It is probably the most important cockroach pest worldwide, (Rehn, 1945).

2.1.1.2 Description:

The German cockroach is one of the smallest of domestic cockroaches, measuring 10-15 mm in length. Males are light yellowish-brown colour, while females are slightly darker. Nymphs are generally black with a light stripe up the mid dorsum. Both nymphs and adults have two longitudinal black parallel bands on the pronotum separated by a lighter stripe. In nymphs the two bands and stripe merge with those of the other thoracic segments. The wings of adults cover the entire abdomen of females and all except the abdominal tip of males. The sexes can be

separated by the darker colour and stout abdomen of females, and by the much longer supra-anal plate of the males. Males also have conspicuous gland openings on the 7th and 8th abdominal tergites. Oothecae are 7-9 mm long with distinct indentations outlining the individual eggs (Roth, 1968).

2.1.1.3 Ecology:

The ecological requisites of this species are warmth, moisture and food and it may be found wherever these conditions are met. In its associations with man these requirements usually mean that it occurs in home kitchens, adjoining food storage rooms, and bathrooms (Cornwell, 1968). It is found in restaurants, food processing plants, city dumps on board ships, and in a variety of other protected environments. Wright and McDaniel (1973) reported that it occurred in housing areas much more frequently than in other situations. Under laboratory conditions it does well at 30°C which may be near its optimum temperature. However, part of its remarkable success is probably attributable to its ability to survive mush less favourable conditions. It has been found living in outside refuse heaps in the middle of winter in temperate areas (Cornwell, 1968). It also occurs out-of-doors, usually as adults or large nymphs (Tsuji & Mizuno, 1972). Thus, in spite of its tropical origin the German cockroach is found in extremely cold regions. It is a general feeder and can survive on a wide diversity of organic matter. It seems to prefer starchy foods (Mallis, 1969).

2.1.2. The Oriental Cockroaches *Blatta orientalis* (Linnaeus):

2.1.2.1 Distributions

The distribution of the oriental cockroach is considerably more restricted than that of the German cockroach. It is largely a species of the temperate zones of the world (Cornwell, 1968). It is widely distributed in the north temperate regions of the New and Old Worlds, being recorded

from as far north as Canada (Hebard, 1917), and other northern countries. It is a dominant pest species in Great Britain (Ragge 1965) and West Germany (Peters, 1961). Its range probably also extends into the subtropics. In South America it appears to be limited to Chile and Argentina, into which it was, very likely, introduced from Spain through early shipping (Rehn, 1945).

2.1.2.2 Description:

The oriental cockroach is of intermediate size measuring 20-27 mm in length. The body is uniformly reddish brown to black in colour, with nymphs tending to be the darkest. The sexes are easily separable because adult females have greatly reduced wings, which give them the appearance of being wingless. Males, on the other hand, have wings that cover two thirds or more of the abdomen. All stages lack a footpad between their tarsal claws, which limits their ability to climb smooth surfaces. Oothecae are 10-12mm in length, are coloured like nymphs and adults, and lack indentations indicating egg position (Cornwell, 1968).

2.1.2.3 Ecology:

This important domiciliary species likes rather cool surroundings. Its preferred temperature range is 20-29^{o}C (Cornwell, 1968). As a result, it is customarily found in lower levels of dwellings where the temperature is cooler. Places as basement cellars, crawl spaces, drainage pipes and sewers, behind cabinets, inside walls, under floor coverings, etc. Its habitat need not be moist. However, moisture must be available to the insects, at higher temperatures. Occasionally, it is found in upper levels of buildings, which it reaches, by following water pipes. Because of its preference for cooler temperatures, it is not surprising that this insect is often found out-of-doors and in unheated buildings even in winter months. It apparently finds adequate shelter in refuse dumps, under the bark of trees, under stones and leaves, and in other similar situations.

There are reports that nymphs cease development in winter (Cornwell, 1968). This may help account for its excessively long nymphal periods. Occasionally, oriental cockroaches become so abundant in their outdoor habitats that they may almost literally overrun an area (Pul'ver, 1973). They are general feeders, but have a preference for starchy foods (Rau, 1945).

2.1.3 The America Cockroach *Periplaneta americana* (Linnaeus):

2.1.3.1 Distribution:

The American cockroach is usually spoken of as being cosmopolitan in its distribution (Princis, 1966). This is perhaps slightly misleading because it probably does not extend as far northward as does the German cockroach. It is believed to have originated in tropical Africa from where it has been widely dispersed through commerce. Originally it spread from Africa to South America, the West Indies and Southern North America (Rehn, 1945). It is presently distributed throughout the tropical and subtropical regions of the world (Nigam, 1933) and many other parts of the northern and southern temperate zones. Thus, it is a virtually cosmopolitan species.

2.1.3.2 Description:

This is a large cockroach which as adult measures about 35-40mm in length. Larger and smaller individuals will occasionally be seen. Males and females are about the same size, but females have stouter abdomens. The sexes can be separated by this feature as well as by the fact that males have both cerci and styli, whereas females lack styli. All stages are shining red to chocolate brown colour. Considerable colour variation occurs in a colony due to the presence of freshly moulted individuals whose colour is not fully developed. The adult pronotum has a prominent yellow to buff coloured submarginal pattern with a darker interior. Nymphs are uniformly coloured except for an indication of the pronotal

pattern in large nymphs. Wings are fully developed in adults of both sexes, extend slightly beyond the abdomen in males, but are approximately as long as the abdomen in females. Ootheacae are rather small measuring about 8mm in length, and are very dark brown (WHO, 1982).

2.1.3.3 Ecology:

The American cockroach prefers warm humid environments as would be expected by its origin. Its preferred temperature is about 28^{o}C, but it is active in the temperature range of 21-33^{o}C. In association with man, this places them in restaurants, food processing plants, grocery stores, bakeries, and other places where food occurs. Historically, they have been of importance as ship galley and cargo hold pests. They are associated with latrines, outhouses, sewer and treatment plants. While not a common household kitchen pest, they do occur in this role. They are general feeders and can survive on almost any organic matter (Cornwell, 1968).

In warm regions they can live outside throughout the year. In temperate climates they survive well outside during summer. There are reports of their occurrence in garbage dumps, unoccupied buildings, trees, mines, and under decaying matter (Cornwell, 1968). Like the oriental cockroach, they can become very abundant as an outside dweller and may overrun a given area (Nigam, 1933).

2.2 Disposal of Human Wastes and Excreta:

By far the greater part of the population of the tropics lives in the rural areas where living conditions are extremely primitive, and those conditions are, by no means, confined to the so-called under-developed areas. Hundred of people may be crowded into a small village, which has neither a proper water supply nor any latrines. Water is obtained from highly polluted sources such as swamps, rivers, holes, or unprotected wells and is stored in and about houses in containers. The surroundings of houses are littered with domestic refuse and the soil is contaminated by indiscriminate defecation. These conditions lead to such diseases as dysentery, typhoid fever, hookworm and other helminthes infections. These examples show how much is needed to be done in the field of environmental sanitation and raising the awareness of people.

Human excreta are highly infective. The basic principle to observe in designing any system of disposal is that it should involve the minimum amount of handling and if possible no handling at all. Direct disposal methods of excreta include the deep trench or pit latrine. The water carriage system of removal of excreta and its subsequent disposal is now the method of choice in large urban communities. This system involves the removal of all-liquid wastes and faecal matter in water which flows by gravity through a system of pipes to the appropriate disposal point (Davey &Lightbody, 1956).

2.3 Public Health Significance of Cockroaches:

A major consideration relating to the actual role of cockroaches in the transmission of disease concerns the likelihood of those insects passing from contaminated areas and media to homes. Though largely confined to buildings in cooler climates, domestic cockroaches may freely leave such structures under tropical and warm temperate conditions. They may frequently migrate to buildings from sewers, cesspools, septic tank and dumps (James & Harwood, 1969).

Sixteen species of cockroaches are considered mechanical vectors of pathogenic organisms, affecting man or have been claimed to bite man (Roth & Willis, 1957); *Blaberus atropos* (Stoll); *Blaberus craniifer* Burm; *Blaberus discoidalis* Serville; *Blattella germanica* (Linnaeus) *Blatta orientalis* Linnaeus (Feranandez & Lembke, 1973); *Eurycotis floridana* (Walker), *Leucophaea maderae* (Fabricius), *Nauphoeta cinerea* (Olivir); *Neostylopyga rhmbifolia* (Stoll); *Periplaneta americana* (Linnaeus); *Periplaneta australasiae* (Fabricius); *Polyphaga saussurei* (Dohrn); *Periplaneta brunnea* Burmeister; *Pycnoscelus surinamensis* (Linnaeus), *Blatta* (Schelfordella); *Lateralis* (Saussure); and *Supella longipalpa* (Fabricius).

Cockroaches have been found naturally contaminated with about fourty different species of bacteria that are pathogenic to vertebrates. Many additional pathogenic bacterial species have been experimentally introduced into cockroaches (Roth & Willis, 1957; 1960; Burgess *et al*., 1973a; 1973b; 1974; Klowden & Greenberg, 1976; Cornwell & Mendes, 1981). They recorded examples of human diseases caused by pathogenic bacteria naturally infecting cockroaches. These include:

Leprosy (*Mycobacterium leprae*); bubonic plague (*Pasteurella pestis*); dysentery (*Shigella alkalescens*); diarrhoea in children (*Shigella paradysenteriae*); urinary tract infection (*Pseudomonas aeruginosa*); boils and abscesses (*Staphylococcus aureus*); pus formation (*Stophylococcus* spp.); urogentital tract and intestine infections (*Escherichia coli*); enteric fever and gastroenteritis (*Salmonella schottmuelleri, S. bredeney,* and *S. oranienburg*); gastroenteritis (*Paracolobactrum aerogenoides, P. coliforme,* and *Salmonella morbificans*); intestinal infections (*Salmonella anatis*), food poisoning (*Salmonella typhimurium, E. coli, Streptococcus faecallis, Pseudomonas areuginosa* and *Clostridium perfringens*); typhoid fever (*Salmonella typhosa*).

The most prominent cockroach species involved in the foregoing examples are *Blattella germanica, Blatta orientalis,* and *Periplaneta americana*, which are the three most common pest cockroaches.

Additional diseases caused by bacteria transmitted to cockroaches experimentally include asiatic cholera, cerebrospinal fever, pneumonia diphtheria, undulant fever, glanders, chicken cholera, anthrax, black leg, tetanus, rat leprosy, and tuberculosis.

The helminthes constitute the second largest group of organisms pathogenic to vertebrates, which are transmitted by cockroaches (Roth &Willis 1957; 1960; Goddeeris, 1980). The eggs of seven helminthes species have been found naturally in cockroaches whereas the eggs of five other species were passed unharmed through the guts of cockroaches and appeared in the faeces. Examples of these are *Schistosoma haematobium, Taenia saginata*, *Ascaris lumbricoides, Ancylostoma duodenale*, and *Necator americanus*. Cockroaches have been shown to

be natural intermediate hosts for twelve species of helminthes, and experimental intermediate hosts for eleven other species. Some examples are *Hymenolepis nana* (Furukawa, 1970), *Moniliformis moniliformis, Gongylonema neoplasticum,* and *Spirura gastrophila* (WHO, 1982).

Laboratory studies have shown conclusively that cockroaches may acquire, maintain, and excrete various viruses (Roth &Willis, 1957). Some examples are the coxsackie virus and several strains of poliomyelitis. They are also suspected of being vectors of infectious hepatitis (Tarshis, 1962). Transmission of viral diseases by cockroaches under natural conditions has not yet been proven, but the existing evidence would make them prime suspects.

Although many non-pathogenic protozoa have been associated with cockroaches, only four species are considered pathogenic to vertebrates. The pathogenic species are *Balantidium coli, Entamoeba histolytica, Giardia intestinalis*, and *Toxoplasma gondii. Trichomonas hominis* and certain other species are of doubtful pathogenic importance (Roth & Willis, 1957).

The fungi *Aspergillus fumigatus* and *A. niger*, sometimes were found associated with pathological conditions, have been reported as occurring naturally in cockroaches as are certain yeasts (Henniger &Windisch, 1976).

2.4Control of Cockroach:

2.4.1 Prevention and Low Risk Control Strategies:

Prevention is perhaps the key to cockroach control. This involves taking steps to minimize cockroach entry into buildings and discourage infestations by promoting cleanliness.

The key to effective control is to lower the carrying capacity of the environment by eliminating the resources needed by cockroaches. The resources needed by them are water, food and shelter. They need these resources to thrive and reproduce. Only very small amounts of water and food may be required. The resources in every habitat determine whether or not an infestation can be established and the potential infestation level. Primary control strategies of cockroaches are to modify environment by limiting water availability, removing their food supply and eliminating hiding places. Low risk control strategies include using special traps, sanitation practices, using soil desiccants and using diatomaceous soil. Relatively harmless products like insect growth hormones are also mentioned in literature (Ogg, 2000).

2.4.2 Chemical Control:

Chemical insecticides remain the most satisfactory means of achieving cockroach control (Cornwell, 1976). Organophosphates, carbamates, synthetic pyrethroids, and organochlorines are the principal types of compounds used on a worldwide basis, especially for residual applications (Grayson, 1959; 1964; 1966; 1975; Burden & Smittle, 1969; Wright & Hillmann, 1973; 1975; 1979 Bennett & Runstron, 1979; Rust & Reierson, 1979; Wright, 1982). Because of resistance of the German cockroach to chlordane and other organochlorine compounds (Grayson, 1966) and because their use has been prohibited in some countries, these

materials have declined in importance as control agents. The current practice is to use materials such as bendiocarb, chlorpyrifos, diazinon, malathion, propetamphos and propoxur for residual spraying against this species. The same materials can also be used to control other cockroach species. In addition, the organorchlorine, chlordane may still be effective against these species if its use is permitted in a given country.

Dusts of 5% chlordane, 2% diazinon, 5% malathion, 1% chlorpyrifos, sodium fluorides, boric acid, or silica gel are occasionally employed in cockroach control (Wright &Hillman, 1973; Wright, 1982). Sometimes combinations of dust and spray treatments are more effective than either alone (Wright &Hillman, 1973). Dusts drift well and can sometimes be used effectively in areas that are difficult or impossible to reach with sprays, such as the interior of hollow walls.

Several chemicals are commercially available as baits for control of cockroaches (MacDonald &Huvar, 1961; Quattrochi, 1968; Tsuji & Ono, 1970). A pellet containing about 2% propoxur has been manufactured. Baits are usually more effective under conditions of low populations of cockroaches or as supplement to other treatment, rather than as a means of controlling high density populations. Paraffin baits containing chemical insecticide, may be used for cockroaches control in damp situations such as sewers and steam tunnels (Wright *et al*., 1973). Baits have also been suggested for use in combination with sprays and dusts (Gupta *et al*., 1973).

Repellents can be useful in cockroach control preventing the insects from invading new areas, from hiding where poisons cannot be placed with safety, or from inhabiting areas where dead cockroaches would cause embarrassment.

2.5 Insecticides:

2.5.1 Propoxur (2- isopropoxy-phenyl-N-methyl carbamate):

This appears as colourless crystal. Its solubility gram per liter at 20^{o}C in water is 1.9. It is hydrolyzable in alkaline conditions. It has a rapid knock-down action and is used as a residual spray for malaria vector control and to control flies, fleas, ticks, mites and cockroaches (WHO, 1984). It acts as a stomach and contact poison and has a fast killing action and remarkable depth action (Anon, Undated).

2.5.2 Malathion (O, O-dimethyl S- (1,2-dicarboethoxy ethyl) dithio-phosphate):

Technical grade malathion pure, is a clear liquid; melting point (m.p) 2.85^{o}C; barometric pressure (b.p) 156-157C/0.7mm Hg; solubility at room temperature 145mg/L water; miscible with most organic solvents; of limited solubility in petroleum oil (Worthing & Walker, 1983).

Malathion has a board spectrum of effectiveness against insects of public health importance. It is used as a residual spray for malaria vector control, as a ultra-low-volume (ULV) spray for mosquito control and as a dust for flea control (WHO, 1984). It is a non-systemic insecticide and acaricide of low mammalian toxicity. It is generally non-phytotoxic but may damage vegetables and squash under glass house conditions. Malathion is metabolized by hydrolysis of the carboxylate and phosphorodithioates esters and oxidation to the phosphorothioate (Worthing &Walker, 1983).

2.6 Chemical Compounds:

2.6.1 Sodium Fluoride (Na F):

This is clear lustrous or white powder insecticide, which is frequently dyed blue. It is soluble in water; very slightly soluble in alcohol. Sodium fluoride is highly toxic by ingestion and inhalation .

Uses: fluoridation of municipal water supplies; treatment of steel; wood preservative, insecticide (not to be used in living plant,), fungicide and rodenticide; chemical cleaning; electroplating; glass manufacture; vireos enamels; preservative for adhesives tooth –paste; radiation detecting systems. (Hawely, 1971).

2.6.2 Boric Acid (H_3BO_3):

This chemical is colourless, odourless scales or white powder, stable in air. It is soluble in water, alcohol and glycerin and moderately toxic in large doses (5 grams for infants).

Uses: Heat-resistant glass (borosilicate glass); glass fibrous; porcelain enamels, boron chemicals, metallurgy (welding flux, brazing copper); fireproofing compositions, fungus control in citrus fruits, ointment and eye wash (Hawley, 1971).

2.7 Natural Plant Products (Usher):

2.7.1 Characteristics and Distribution:

Calotropis procera Ait, locally known as usher, belongs to the family Asclepiadaceae. It is ashy glabrous, ascending to erect, soft woody shrubs or small trees up to 300 cm high, with yellow –brown, thick, corky, longitudinally fissured barks. Leaves opposite sessile or subsessile; laminas obovate-elliptic, 10.5-16.5x7.5-10cm, apex obtuse to mucronate, base cordite, margin entire. Inflorescence axially, clustered supumbellate cymes, up to 7 cm long. Flowers greenish-white with violet tips. Fruits follicle, inflatted, subglobose, 7.5-15.5x5.7 cm, green. Seed ovate, 0.03 cm long, brownish.

Its found in low land plains, water catchment areas, waste grounds. It is widespread throughout Sudan (El Gahazali, *et al* 1997).

2.7.2 Chemical Constituents of *Calotropis procera*:

The root contains mainly two cardenolides, two steroid and quercetin –3- rutinoside. The stem also contains cardenolides and quercetin-3- rutinoside. The leaves contain all the cardenolides present in the stem except one, in addition to ascharin. Quercetin-3- rutinoside is also found in the leaves. The plant latex contains a number of cardenolides in addition to quercetin –3- rutinoside. The seeds also contain cardenolides. The flowers contain two flavonoids (El Ghazali *et al*. 1997).

2.7.3 Use of Usher Plant:

It has been suggested to be used for different commercial purposes since the beginning of last century like rubber extraction (Budde, 1937; Dubosc, 1927), textile and paper manufacturing (Dubose, 1927; Shah *et al.,* 1981) and recently as a source of fuel and energy (William & Casali, 1981).

The plant was reported to be beneficial in a number of human ailment and is used by the folk medicine practitioners of Africa and Saudi-Arabia as purgative, antirheumatic, diaphoretic, expectorant, anti-dysenteric and for treatment of bronchial asthma (Al. Yaha, *et al,* 1986).

2.7.4 Insecticidal Activity of Sodom Apple (usher):

According to Wat, *et al*. (1962) usher plant contains insecticidal ingredients and the leaf is used for destroying fowl lice. The root extracts had shown strongly positive antibiotic activity. Sharma (1983) reported that flower extract of *C. procera* had no antifeedant action against adults of *Rhizopertha dominica.* However, two years later Sharma (1985) reported antifeedant action against larvae of the same insect. In all feeding experiments the food intake by the larvae increased as the concentration of the flower extract of *C. procera increased.* When extracts of flower of *C. procera* were mixed with wheat flour and provided to 1st, 2nd, 3rd, and 4th instar larvae of the stored products pest *R. dominica* in the laboratory, larval mortality increased and the rate of adult emergence decreased by starvation as the concentration of the extract increased from 0.1 to 1000 ppm. The youngest larvae were more susceptible than the older ones.

Girdhar and Pkarnd (1984) reported that *C. procera* latex had toxic effect to the larvae of *Anopheles stephensi, Culex fatigans*, *Culex quinquefasciatus* and *Aedes aegypti* giving 100% mortality to eggs and larvae under laboratory conditions.

Ahmed (1993) found that *C. procera* had antifeedant, repellent and insecticidal action against *Trogoderma granarium* larvae. Two fifth grams of powder of flower, roots and leave of *C. procera* when mixed with 20 grams of wheat seeds and provided to the 1st, 2nd, 3rd, and 4th insatr larvae retarded the larval development. However, the same author found that aqueous solution of the roots, leaves and flowers at 1.25, 2.5

and 5% concentration failed to protect the seed three months after treatment. Larval development was retarded compared to the control. Water and ethanolic extract of these parts (flowers, roots and leaves) showed a good dose related antifeedant effect against test insects. The leaves ethanolic extracts were the most effective treatment in retarding larval development.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study of the Hygienic Importance of Sudanese Cockroaches:

3.1.1 Collection and Maintenance of Cockroaches:

For the purpose of isolation of the pathogenic bacteria, cockroaches were collected from damp places like septic tanks in the University of Khartoum. Individuals of each species were kept separately in wood cages measuring 24x18x14cm. The cockroaches were fed on dry bread. Water was provided in glass Petri dishes.

3.1.2 Culture Media:

Five different media were prepared as instructed by the manufacturer for the purpose of culturing, isolation and differentiation of pathogenic bacterial species such as the members of the family Entero-bacteriaceae. The media used were:

3.1.2.1 Nutrient Agar (NA):

This was prepared by dissolving 7 grams of the medium in 250 ml of distilled water in a conical flask and heating in a water bath. The preparation was sterilized in an autoclave at 15 Ibs pressure and 121 ^{o}C for 15 minutes.

3.1.2.2 Desoxycholate Citrate Agar (DCA):

To prepare this medium, 12.875 grams of DCA were suspended in 250 ml of distilled water in a conical flask. It was allowed to stand for 15 minutes and brought to boiling to dissolve completely. Then it was cooled down to 50-55^{o}C.

3.1.2.3 *Salmonella Shigella* Agar (SSA):

The medium was used at a concentration of 14.25 grams in every 250 ml of distilled water. The suspension was brought to boiling with frequent agitation and was allowed to simmer gently to dissolve the agar. Then it was cooled to about 50^{o}C prior to pouring into Petri dishes.

3.1.2.4 Eosin Methylene Blue Agar (EMBA):

This medium was prepared by dissolving 9 grams of EMB in 250 ml of distilled water in a conical flask. The suspension was boiled in a water bath and autoclaved at 15 Ibs pressure and 121^{o}C for 15 minutes.

3.1.2.5 Mannitol Salt Agar (MSA):

The medium was prepared by dissolving 27.75 grams in 250 ml of distilled water in a conical flask and heating in a water bath. The preparation was sterilized in an autoclave. Then it was cooled to 50-55^{o}C (Cheesbrough, 1991).

3.1.3 Isolation and Inoculation of Bacteria from Cockroaches:

To isolate bacteria from the body surface, 25 individual insects of the same species were washed each in a separate sterilized test tube containing 3ml of sterilized distilled water. The tubes were vigorously shacked for 5 minutes. The wash (inoculum) was transferred into a fresh sterilized test tube.

These inocula were inoculated in previously prepared media by spreading the wash on the media surface using a sterile syringe. Twenty-five washes were inoculated in each of the five inoculation media. These were then incubated for 24 hours at 37^{o}C.

This procedure was repeated 3 times using cockroaches of the same species collected from 3 different sites. The three different species were treated in the same way.

Sterilization of culture media, water, test tubes and glass Petri-dishes was carried out according to Cheesbrough (1991) and Carpenter (1972).

3.1.4 Detection and Identification of Pathogenic Bacteria:

The presence of bacteria was tested by inoculation in nutrient agar. Differentiation of different groups of bacteria was made by inoculation of the wash in differential media. The medium EMB differentiates between lactose fermented and non-lactose fermented. Then selective media, which permit the growth of one group of bacteria while inhibiting the growth of other groups like DCA and SSA which were used to isolate *Salmonella* and *Shigella* species. The medium MSA was used to isolate *Staphylococcus aureus*.

Identification of unknown bacteria taken from the external surface of cockroaches was carried out by the classic dichotomous keys beside using the API 20E manual biochemical systems for microbial identification. (Prescott, *et al*.1993).

The key was coupled with the biochemical tests for the identification of bacteria from the wash.

3.1.4.1 Microscopic Study:

Bacteria were suspended in water on a clean microscopic slide and spread by a sterile wire loop (holder length 6 cm and loop diameter 0.2 cm). The flame-sterilized loop was allowed to cool before it was used. Smear slides were left on the bench to air-dry. The slides were passed rapidly (smear uppermost) three times through a flame, then allowed to cool before staining (Cheesbrough, 1991).

3.1.4.1.1 Gram Stain:

Differential staining techniques (Gram stain) were used to divide bacteria into the two major classes which are either Gram-positive-or Gram negative.

The smear was stained with the primary stain crystal violet. It was then covered with iodine solution. This was followed by decolorizing with 95 percent alcohol and then it was counter-stained with safranin.

Organisms that retain the purple primary stain were designated Gram-positive; Gram-negative cells lose the primary stain when decolorized with alcohol and stain with the relatively weak secondary pink dye (Carpenter, 1972; Cheesbrough, 1991).

3.1.4.1.2 Simple Staining:

Simple staining methods were used to detect the shape and arrangement of bacteria for identification.

The fixed smears were covered with basic dyes such as crystal violet for 15 seconds. Stained smears were rinsed briefly with water to remove excess stain, dried in air and examined under the microscope (Carpenter, 1972).

3. 1.4. 2 Aerobioses:

Thioglycolate medium was used for cultivation of anaerobes, aerobes and facultative bacteria.

The medium was prepared by dissolving 7.45 grams in 250 ml of distilled water in a conical flask and heating in a water -bath. Then the preparation was sterilized in an autoclave at 15 Ibs pressure and 121^{o}C for 15 minutes.

Aerobioses of bacteria was tested by immersing the organism in a test tube containing 5 ml of the above preparation and incubating at 35-37^{o}C for 24 hours. Growth at the surface indicates aerobic organisms, growth in the depths of the medium indicates anaerobes, and growth throughout is obtained with facultative anaerobic organism.

3.1.4. 3 Catalase Test:

This test differentiates those bacteria (+ve Gram) that produce the enzyme catalase such as staphylococci from catalase non-producing bacteria such as streptococci.

Catalase activity of bacteria was tested by immersing the organism in 3 percent of hydrogen peroxid (H_2O_2) in a test-tube, using a glass rod. Catalase enzymes release bubbles of oxygen (Cheesbrough, 1991).

3.1.4.4 Coagulase Test:

This test was used to differentiate *Staphylococcus aureus* which produces the enzyme coagulase, from *S.epidermis* and *S. saprophyticus* which don't produce coagulase.

Coagulase enzyme was detected by adding 5 drops of test organism (18-24 hour in broth culture) in a test-tube containing 0.5 ml of dilute plasma (0.1ml plasma in 0.9ml of saline). Then the tube was incubated at 35-37^{o}C for one hour. Coagulase causes plasma to clot by converting fibrinogen to fibrin. (Cheesbrough, 1991).

3.1.4.5 Oxidase Test:

The oxidase test is used to assist in the identification of the species which produce oxidase enzyme such as *Pseudomonas , Neisseria, Vibrio* and *Pasteurella* species.

A piece of filter paper was soaked with a few drops of oxidase reagent. A colony of the test organism was smeared on the filter paper.

The phenylenediamine in the reagent was oxidized to a blue-purple colour from oxidase-producing organism within 10 seconds.

3.1.4.6 API 20E:

This is an identification system for Enterobacteriaceae and other non-fastidious Gram-negative rods which uses 21 standardized and miniaturized biochemical tests and a database (See Plate1 and Appendix **1).**

3.1.4.6.1 Preparation of the Strip:

Five ml of distilled water were distributed into the honey-combed well of the tray (incubation box) to create a humid atmosphere. Then the strip was removed from its packaging and placed in the incubation box.

3.1.4.6.2 Preparation of the Inoculum:

A single well-isolated colony, from slant agar, was suspended in a sterile test tube containing 5ml of 0.85% sodium chloride and then emulsified to achieve homogeneous bacterial suspension.

3.1.4.6.3 Inoculation of the Strip:

The tube and capule of test sodium citrate [CIT], creatine sodium pyruvate [VP] and Kohn's gelatin [GEL] were filled with the bacterial suspension by a sterile syringe. Then the tubes of the other tests were filled and the incubation box was closed by its lid and incubated at 35-37^{o}C for 18-24 hours.

3.1.4.6.4 Reading the Strip:

After 18-24 hours at 35-37^{o}C, the strip was read by referring to the reading table (Appendix II). All the spontaneous reactions were recorded on the result sheet.

Identification was obtained with the numerical profile. On the result sheet, the tests were separated into groups of 3 and a value 1,2 or 4 was indicated for each. By adding together the values corresponding to positive reactions within each group, a 7-digit profile number was obtained for the 20 tests of the API 20E strip. The oxidase reaction constitutes the 21st test and had a value of 4 if it was positive.

In some cases, the 7-digit profile was not discriminatory enough and there were six supplementary tests carried out to form 9-digit profile (Appendix III). The name of the bacterium was determined by referring to the API profile index (Anon, 2000).

3.2 Control of Cockroaches:

3.2.1 Collection and Maintenance of Cockroaches:

Cockroaches were collected and maintained as described in 3.1.1.

3.2.2 Preparation of Stock Solutions:

Stock solutions of each of propoxour 2%, malathion 8%, sodium-fluoride 12.5%, boric acid 20%, usher leaves 25% and usher whole fruits 25%, were prepared.

Two percent of propoxur 5% was prepared by weighing 40 grams of it in a volumetric flask. Then the volume was made up to 100 ml using distilled water and was mixed thoroughly.

Eight percent stock aqueous solution of malathion was prepared by adding 14 ml of malathion 57% to 86 ml of distilled water in 100 ml volumetric flask.

Sodium fluoride 12.5% was prepared by weighing 12.5 grams of it in a volumetric flask. Then it was completed to 100 ml using distilled water and shaking vigorously. Boric acid 20 % was prepared in the same way.

Stock aqueous extracts of leaves and whole fruit, of usher were prepared by treating various sound plant parts similarly. After cleaning and drying at room temperature, each plant part was separately powdered with an electric mill until very fine particles were obtained.

Twenty five percent of usher leaves aqueous extracts was prepared by weighing 25 grams of leaves powder in a volumetric flask and making up to 100 ml mark with distilled water. The solutions were thoroughly shaken by hand for 15 minutes then left to settle for a while. Shaking of the mixtures was repeated 5 times and the aliquots were allowed to stand for one day before filtering through a mesh sieve, and keeping in brown bottles for immediate use or use within three days of storage. The sames

procedure was followed to prepare 25% of usher whole fruit aqueous extracts.

3.2.3 Preparation of Baits:

Blank baits were prepared by mixing 20 grams of wheat flour and 20 grams of table sugar. Then water was added to the mixture. The paste was then thoroughly mixed using a glass-rod and poured into Petri dishes. The paste was completely dried in an oven at 100^{o}C. For the preparation of treated baits, 10 ml of the respective test agents were added to the 40 grams of the blank baits (10ml in each Petri dish). Controls were prepared by adding distilled water to the blank bait followed by oven drying at 100 ^{o}C.

3.2.4 Experiments:

3.2.4.1 Exploratory Tests:

It was necessary to conduct some exploratory tests to determine roughly the toxicity of each treated bait. This was carried out by offering widely separated insecticide treated baits to the insects in batches of 10 insects.

3.2.4.2. Bioassay Tests:

Once the extent of the toxicity range was determined, baits containing logarithmically prepared doses were used. In every experiment 30 adult cockroaches were kept in the experimental cage (Plate 2) and offered baits containing the appropriate insecticide concentration. In control experiments, blank baits were offered. Experiments lasted for 24 hours and dead cockroaches were removed as soon as discovered.

3.2.5 Statistical Analysis:

Data on mortality were subjected to probit regression analysis according to Busvine (1957). The results of the analyzed data are presented in tabular and graphical forms. The relevant statistical data for each table are also presented. In each case the equation of the straight line: $Y = a + bX$, was computed where, y ≡ probit mortality; a ≡ constant representing the intersect the regression line makes with the vertical axis;

b ≡ a constant representing the slope (tanθ) of the line on the horizontal ; x ≡ log dose producing y mortality.

From the equation 24 hours LD_{50} and LD_{95} could be determined together with some relevant statistical data, including standard deviation (S.D) and 95% fiducial limits (95% F.L). The toxicity of a substance was determined by: (a) The value of 24 hours LD_{50}, the lower the value, the more potent is the test substance (b) The extent of the toxicity range and the slope expressed in degrees, indicate the knocking down effect of the toxicant. The longer the interval between the concentration giving 0.0% mortality and that producing 100% mortality is, the slower the action of the toxicant.

CHAPTER FOUR

RESULTS

4.1 Hygienic Importance of Sudanese Cockroaches:

This part of the work is concerned with the isolation and identification of pathogenic bacteria associated with the cockroaches in Sudan.

Table (I) shows disease causing bacteria isolated from the external surface of the adults of *Battela germanica, Blatta orientalis* and *Periplaneta americana.* Each of the three insect species carried all nine pathogenic bacterial species. Out of the 75 cockroaches examined individually two thirds of *B. germanica*, over four fifths of *B. orientalis* and all *P. americana* carried the disease causing bacteria.

Plate (3) shows the inoculation of the wash in the media and plate (4) shows Grams –staining bacteria. Gram-positive cells retain the purple primary stain, while Gram-negative cells lose the primary stain when decolorized.

The properties of Gram-positive bacteria isolated are listed in Table (II). Coagulase test was used to identify *Staphylococcus aureus*.

Gram- negative bacteria were detected by the manual biochemical systems for rapid identification. Plates (5A-12A) show certain biochemical characteristics by the API 20E, the main 20 and 6 supplementary test, results were converted to a 9-digit profile number on the result sheet in Plate (5B- 12B). All Gram-negative bacteria isolated were found to belong to the family Enterobacteriaceae, except *Pseudomonas* which belong to the family Pseudomonadaceae.

Plate (13) shows the preservation of laboratory culture and maintenance of control species by agar slope, slant sub culturing.

Table (I): Bacteria isolated from the body surface of adults of *Blattela germanica*, *Blatta orientalis* and *Periplaneta americana* collected from damp places in the University of Khartoum.

No.	Bacterial species	Gram reaction	*B. germanica*	*B. orientalis*	*P. americana*
1	*Staphylococcus aureus*	+ve	+	+	+
2	*Escherichia coli*	-ve	+	+	+
3	*Klebsiella pneumonia*	-ve	+	+	+
4	*Shigella* Spp.	-ve	+	+	+
5	*Proteus mirabilis*	-ve	+	+	+
6	*Serratia* spp.	-ve	+	+	+
7	*Salmonella* spp.	-ve	+	+	+
8	*Enterobacter gergoviae*	-ve	+	+	+
9	*Pseudomonas fluorescens*	-ve	+	+	+
	No. of bacterial sp.		9	9	9
	No. of cockroaches tested		75	75	75
	No. of infected cockroaches		50	65	75

Table(II): Biochemical properties of Gram-positive organism isolated from adults of *Blattela germanica*, *Blatta orientalis* and *Periplaneta americana.*

No.	Isolated strain	Gram reaction	Shape	Growth in air	Catala-se	Coagulase
1	*Staphylococcus aureus*	+ve	Cocci	+ve	+ve	+ve

More Gram-negative bacteria were isolated from cockroaches. However, Gram-positive bacteria were less prevalent in cockroach specimen investigated. Because most of Gram-negative bacteria belong to the Enterobacteriaceae and it can be found in the intestinal tract of humans and animals, and in soil.

4.2 Palatability and Toxicity of Treated-baits to Cockroaches:

Previous work showed that cockroaches prefer starchy food. In this study insecticides, chemical compounds and natural plant products were offered to them in starchy baits. To have any toxic effect, the food must be palatable to the insects.

In all palatability experiments the consumed weight was calibrated by subtracting 3 grams from the difference between initial and final weight. This value is the loss of weight due to water evaporation during 24 hours. Each 1 gram of treated baits contain 1/4 ml of the tested concentration. In all cases blank baits were more palatable than treated baits. In all feeding experiments palatability decreased with increase of dose. Mortality on the other hand increased linearly with dose. The response of the test animals in terms of probit mortality was found to form a linear relationship with log dose.

4.2.1 Palatability and Toxicity of Toxicants Against Adults of *Blattela germanica*:

Table (III) summarizes the toxic effects of the tested substances to adults of the German cockroaches. It shows the calculated 24 hours LD_{50} of each toxicant together with the slope expressed in degrees.

As can be seen in Tables (IVA-IXA) and Figures (1A-6A) increase of toxicant concentration within certain range causes negligible decrease in palatability.

Tables (IVB-IXB) and Figures (1B-6B) show the empirical and calculated mortality and dose/response regression line of the toxicant used against German cockroaches, respectively.

Table (III): The 24 hours LD_{50} with 95% fiducial limits of the tested materials aqueous extracts treated bait against adults of *Blattela germanica*.

Toxicant	LD_{50}% (W/V)			Slope in degrees
	Upper limit	Average	Lower limit	
Propoxur	1.6703	1.4242	1.2145	82
Malathion	4.0907	3.6314	3.2240	84
Sodium fluoride	9.0178	8.2916	7.6225	89
Boric acid	11.9978	10.9802	10.0485	88
Usher leaves	13.6427	12.3608	11.1970	86
Usher whole-fruits	15..0383	13.6670	12.4222	87

4.2.1.1 Palatability and Toxicity of Insecticides Against Adults of *Blattela germanica*:

Tables (IVA&IVB) and figures (IA &IB) show that propoxur is palatable by and toxic to *B. germanica*. It is clear that propoxur dose needed to kill 50% of the population during 24 hours (LD_{50}) is 1.4242% (1.16 ml in 4.65 grams). This mortality takes place after the consumption of 4.65 grams of bait containing the above mentioned dose.

When fed on malathion, LD_{50} is 3.6314% (1.22 ml in 4.9 grams) and the weight corresponding to it is 4.9 grams (Tables VA & VB and Figures 2A & 2B).

4.2.1.2 Palatability and Toxicity of Chemical compounds Against Adults of *Blattela germanica*:

When known concentrations of sodium fluoride and boric acid were used against *B. germanica* palatability values were 7.41grams and 11.08 grams respectively and LD_{50} values were 8.2916% (1.85 ml in 7.41 grams) and 10.9802% (2.77 ml in 11.08 grams) respectively. These are shown in Tables (VIA-VIIA &VIB-VIIB) and Figures (2A-3A & 2B-3B).

4.2.1.3 Palatability and Toxicity of Natural Plant Products Against Adults of *Blattela germanica*:

Palatability and LD_{50} of usher leaves and usher whole fruits are shown in Tables (VIIIA-IXA & VIIIB-IXB) and Figures (5A-6A &5B-

6B) respectively. Palatability of usher leaves is 8.38 grams and its LD_{50} is 12.3608%(2.10 ml in 8.38 grams) while palatability of usher whole fruits is 9.49 grams and its LD_{50} is 13.6670% (2.7 ml in 9.49 grams).

Table (IVA): Palatability of propoxur to adults of *Blattela germanica* and resulting mortality.

Dose %	Initial weight g.	Final weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	49.8	37.8	12.0	100	0
0.4577	49.9	41.8	8.1	68.3	10
0.7483	49.9	42.4	7.5	62.5	22
0.9568	49.9	43.7	6.2	51.7	35
1.2234	50.0	44.5	5.5	45.8	51
1.5642	50.0	45.7	4.3	35.8	62
2.0000	50.0	46.7	3.3	27.5	82

Table (IVB): Toxicity of propoxur against adults of *B. germanica.*

Dose %	Log dose +1	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
0.4577	0.6605	10	3.72	8	3.57
0.7483	0.8740	22	4.23	24	4.30
0.9568	0.9808	35	4.61	37	4.66
1.2234	1.0875	51	5.03	51	5.03

1.5642	1.1943	62	5.31	66	5.40
2.0000	1.3010	82	5.92	78	5.76

Regression equation :Y = 1.3034 +3.466X

Slope in degrees : 82

Log LD_{50} : 1.1536= > LD_{50}: 1.4242.

Log LD_{95} : 1.5486 = > LD_{95}: 3.5370

Variance (V) : 1.2461×10^{-3}

Standard Deviation (SD) : 0.0353

Log LD95% fiducial limits : 1.1536 ± 0.0692.

Table (VA): Palatability of malathion to adults of *Blattela germanica* and resulting mortality.

Dose %	Initial weight g.	Final weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	50.0	36.9	13	100	0
2.0000	50.0	42.6	7.3	56.2	15
2.8284	50.0	43.7	6.2	47.7	31
3.3635	50.0	45.0	5.0	38.5	45
4.0000	50.0	45.2	4.8	36.9	60
5.6565	50.0	46.3	3.7	28.5	73
6.7271	50.0	47.5	2.5	19.2	89

Table (VB): Toxicity of malathion against adults of *B. germanica*.

Dose %	Log dose	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
2.0000	0.3010	15	3.96	15	3.97
2.8284	0.4515	31	4.50	33	4.57
3.3635	0.5267	45	4.87	45	4.87
4.0000	0.6020	60	5.25	56	5.17
5.6565	0.7525	74	5.61	78	5.77

6.7271	0.8278	89	6.23	8.5	6.06

: Y= 2.7692 +3.9830X. Regression equation

Slope in degrees : 84.

Log LD_{50} : 0.5601= > LD_{50}: 3.6314.

Log LD_{95} : 0.9643= > LD_{95}: 9.2105.

Variance (V) : 6.9696×10^{-4}

Standard Deviation (SD) : 0.0264.

Log LD95% fiducial limits : 0.5601± 0.0517.

Table (VIA): Palatability of sodium fluoride to adults of *Blattela germanica* and resulting mortality.

Dose %	Initial weight g.	Final Weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	50.0	37	13	100	0
5.5903	50.0	40.9	9.1	70	15
6.8359	50.0	41.8	8.2	63.1	35
8.3593	50.0	42.9	7.3	56.2	50
10.2221	50.0	44.0	6.0	46.2	64
11.3038	50.0	44.5	5.5	42.3	76
12.5000	50.0	45.0	5.0	38.5	89

Table (VIB): Toxicity of sodium fluoride against adults of *B. germanica*.

Dose %	Log dose	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
5.5993	0.7474	15	3.96	16	4.00
6.8359	0.8348	35	4.61	31	4.51
8.3593	0.9222	50	5.0	51	5.02
10.2221	1.0095	64	5.36	69	5.5
11.3038	1.0532	76	5.71	73	5.78
12.5000	1.0969	89	6.23	85	6.04

: Y = -0.3566+5.8312X. Regression equation

Slope in degrees : 89.

Log LD_{50} : 0.9186= >LD_{50}: 8.2916.

Log LD_{95} : 1.1947=>LD_{95}: 15.6583.

Variance (V) : 3.4707×10^{-4}.

Standard Deviation (SD) : 0.0186.

Log LD 95% fiducial limits : 0.9186± 0.0365

Table (VIIA): Palatability of boric acid to adults of *Blattela germanica* and resulting mortality.

Dose %	Initial weight g.	Final weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	50.0	37.0	13.0	100	0
6.6907	50.0	37.5	12.5	96.1	10
8.1822	50.0	38.0	12.0	92.3	25
10.0062	50.0	38.5	11.5	88.5	45
12.2369	50.0	39.0	11.0	84.6	65
14.9648	50.0	39.8	10.2	78.5	75
18.3008	50.0	41.0	9	69.2	85

Table (VIIB): Toxicity of boric acid against adults of *B. germanica*.

Dose %	Log dose	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
6.6907	0.8255	10	3.72	13	3.87
8.1822	0.9129	25	4.33	25	4.33
10.0062	1.0003	45	4.87	42	4.79
12.2369	1.0877	65	5.39	60	5.25
14.9648	1.1751	75	5.67	76	5.70
18.3008	1.2625	85	6.04	87	6.16

Regression equation: : Y=-0.4501 +5.2375X.

Slope in degrees	: 88.
Log LD_{50}	: 1.0406 = > LD_{50}: 10.9802.
Log $_{95}$	: 1.3480 = > LD_{95}: 22.2861.
Variance (V)	: 3.8487 > 10^{-4}
Standard Deviation (SD)	: 0.0196.
Log LD95% fiducial limits	: 1.0406 ± 0.0385

Table (VIIIA): Palatability of usher leaves to adults of *Blattela germanic*a and resulting mortality.

Dose %	Initial weight g.	Final Weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	49.9	37.4	12.5	100	0
7.0627	49.9	38.2	11.7	93.6	13
8.8914	49.9	39.7	10.2	81.6	23
11.1936	49.9	40.0	9.1	72.8	43
14.0919	49.9	41.7	8.2	65.6	61
17.7407	50.0	42.1	7.9	63.2	78
22.3342	50.0	43.0	7.0	56	90

Table (VIIIB): Toxicity of ushers leaves against adults of *B. germanica*.

Dose %	Log dose	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
7.0627	1.8490	13	3.87	12	3.84
8.8914	1.9490	23	4.26	25	4.32
11.1936	1.0490	43	4.82	42	4.80
14.0919	1.1490	61	5.28	61	5.27
17.7407	1.2490	78	5.77	77	5.75
22.3342	1.3490	90	6.28	89	6.23

Regression equation : $Y= -1.0920+4.7548X$.

Slope in degrees : 86.

Log LD_{50} : 1.0920 = >LD_{50}: 123608.

Log LD_{95} : 1.7316 = >LD_{95}: 26.9522.

Variance (v) : 4.7803×10^{-4}

Standard Divination (SD) : 0.0219.

Log LD 95% fiducial limits : 1.0920 ±0.0429.

Table (IXA): Palatability of usher whole fruits to adults of *Blattela germanica* and resulting mortality.

Dose %	Initial weight g.	Final weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	49.8	36.8	13	100	0
7.0627	49.9	37.7	12.2	93.8	8
8.8914	49.9	38.4	11.5	88.5	18
11.1936	50.0	39.9	10.1	77.7	38
14.0919	50.0	40.7	9.3	71.5	50
17.7407	50.0	41.5	8.5	65.4	69
22.3342	50.0	42.0	8.0	61.5	85

Table (IXB): Toxicity of usher whole fruits against adults of *B. germanica*

Dose	Log dose	Empirical mortality	Calculated mortality

%		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
7.0627	0.8490	8	3.59	7	3.57
8.8914	0.9490	18	4.08	17	4.07
11.1936	1.0490	38	4.69	33	4.57
14.0919	1.1490	50	5.00	53	5.07
17.7407	1.2490	69	5.50	72	5.57
22.3342	1.3490	85	6.04	86	6.06

: Y = -0.6679 +4.9907X. Regression equation

Slope in degrees : 87.

Log LD_{50} : 1.1357 =>LD_{50}: 13.667.

Log LD_{95} : 1.4583 =>LD_{95}: 28.7284.

Variance (V) : 4.4897×10^{-4}.

: 0.0212. Standard Deviation (SD)

: 1.1357±0.0415. Log LD95%fiducial limits

4.2.2 Palatability and Toxicity of Toxicants Against Adults of *Blatta orientalis:*

All treated-baits were found to have potency against adults of *Blatta orientalis*. Table (X) gives a summary of toxic effects of the substances tested against the oriental cockroach showing 24 hours LD50% of each toxicant and knock down determined by the angle the dose response regression line makes with the horizontal line.

As can be seen in Tables (XIA-XVIA) and Figures (7A-12A) increase of toxicant concentration within certain range causes negligible decrease in palatability.

Table (XIB-XVIB) and Figure (7B-12B) shows the insecticidal activities of treated baits during 24 hours.

4.2.2.1 Palatability and Toxicity of Insecticides Against Adults of *Blatta orientalis*:

When known concentrations of propoxur and malathion were used against *B. orientalis*, palatability values were 9.90 grams and 8.80 grams, respectively and LD_{50} values were o.8583% (2.47 ml in 9.90 grams) and

3.4324% (2.2 ml in 8.80 grams), respectively. These are shown in Tables (XIA-XIIA &XIB-XIIB) and Figures (7A-8A&7B-8B).

4.2.2.2 Palatability and Toxicity of Chemical Compounds Against Adults of *Blatta orientalis*:

Palatability and LD_{50} of sodium fluoride and boric acid are shown in Tables (XIIIA-XIVA &XIIIB-XIVB) and Figures (9A-10A &9B-10B), respectively. Palatability of sodium fluoride is 9.76 grams and its LD_{50} is 4.8955% (2.44 ml in 9.76 grams) while palatability of boric acid is 11.04 grams and its LD_{50} is 5.5312% (2.76 ml in 11.04 grams).

Table (X): The 24hour LD_{50} with 95% fiducial limits of the tested materials aqueous extracts treated baits against adults of *Blatta orientalis*.

Toxicant	LD50% (W/V)			Slope in degrees
	Upper limit	Average	Lower limit	
Propoxur	0.9936	0.8583	0.7417	80
Malathion	3.7827	3.4324	3.1175	88
Sodium fluoride	5.3852	4.8955	4.4504	87

Boric acid	6.1348	5.5312	4.9865	87
Usher leaves	9.5082	8.6653	7.8977	88
Usher whole-fruits	9.7814	8.8837	8.0686	87

Table (XIA): Palatability of propoxur to adults of *Blatta orientalis* and resulting mortality

Dose %	Initial weight g.	Final weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	49.8	33.3	16.5	100	0
0.4077	50.0	36.0	12.0	72.7	20
0.9628	50.0	36.6	11.4	69.1	37
0.9030	50.0	39.9	10.1	61.2	45
1.1771	50.0	40.7	9.3	56.4	65
1.5343	50.0	42.0	8.0	48.5	80
3.0000	50.0	42.8	7.2	43.6	90

Table (XIB): Toxicity of propoxur against adults of *B. orientalis.*

Dose %	Log dose +1	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
0.4077	0.6103	20	4.16	16	4.01
0.6928	0.8406	37	4.67	39	4.72
0.903	0.9557	45	4.87	53	5.07
1.1771	1.0708	65	5.39	66	5.42
1.5343	1.1859	80	5.84	78	5.77
2.0000	1.3010	90	6.21	87	6.12

Regression equation : Y=- 2.1554 +3.0467X

Slope in degrees : 80

Log LD_{50} : 0.9337 => LD_{50}: 0.8583

Log LD_{95} :1.4621 =>LD_{95} : 2.8980

Variance (V) : $1.0\ 509 \times 10^{-3}$

Standard Deviation (SD) : 0.0324

Log LD 95% fiducial limits : 0.9337± 0.0635

Table (XIIA): Palatability of malathion to adults of *Blatta orientalis* and resulting mortality

Dose %	**Initial weight g.**	**Final weight g.**	**Consumed weight g.**	**Consumed weight %**	Mortality **%**
0.0000	50.0	33.7	16.3	100	0
2.0000	50.0	38.8	11.2	68.7	12
2.8284	50.0	40.0	10.0	61.3	33

3.3635	50.0	41.0	9.0	55.2	47
4.0000	50.0	41.8	8.2	50.3	65
5.6568	50.0	42.7	7.3	44,8	85
6.7271	50.0	43.5	6.5	39.9	95

Table (XIIB): Toxicity of malathion against adults of *B. orientalis*.

Dose %	Log dose	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
2.0000	0.3010	12	3.82	11	3.77
2.8284	0.4515	33	4.56	33	4.56
3.3635	0.5270	47	4.92	48	4.95
4.0000	0.6020	65	5.39	64	5.35
5.6568	0.7525	85	6.04	87	6.14
6.7271	0.8278	95	6.61	94	6.53

Regression equation : Y=- 2.1900+5.2464X.

Slope in degrees : 89

Log LD_{50} : 0.5358 => LD_{50}: 3.4324

Log LD_{95} : 0.8425 => LD_{95} : 6.9578.

Variance (V) : 4.6015×10^{-4}

Standard Deviation (SD) : 0.0215

Log LD 95% fiducial limits : 0.5359± 0.0402

Table (XIIIA): Palatability of sodium fluoride to adults of *Blatta orientalis* and resulting mortality.

Dose %	Initial weight g.	Final weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	50.0	34	16.0	100	0
2.5000	50.0	39	12.0	75	10
3.7384	50.0	38.9	11.1	69.4	25
4.5715	50.0	39.8	10.2	63.8	43
5.5903	50.0	40.6	9.4	58.8	61
6.8359	50.0	41.3	8.7	54.4	75
8.3593	50.0	42.0	8.0	50.0	90

Table (XIIIB): Toxicity of sodium fluoride against adults of *B. orientalis*.

Dose %	Log dose	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
2.5000	0.3979	10	3.72	8	3.57
3.7384	0.5727	25	4.33	28	4.42

4.5715	0.6601	43	4.82	44	4.85
5.5903	0.7474	61	5.28	61	5.28
6.8359	0.8348	75	5.67	76	5.71
8.3593	0.9222	90	6.28	87	6.14

: Y=1.6131+4.9100X. Regression equation

: 87 Slope in degrees

: 0.6898 => LD_{50}: 4.8955. LD_{50} Log

Log LD_{95} : 1.0177 => LD_{95} : 10.4153.

Variance (V) : $4.4636x10^{-4}$.

: 0.0211 Standard Deviation (SD)

0.6898± 0.0414. Log LD 95% fiducial limits

Table (XIVA): Palatability of boric acid to adults of *Blatta orientalis* and resulting mortality.

Dose %	Initial weight g.	Final weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	50.0	34.0	16	100	0
3.6582	50.0	36.5	13.5	84.4	14
4.4738	50.0	37.8	12.2	76.3	27
5.4711	50.0	38.8	11.2	70.0	55
6.6907	50.0	39.7	10.3	64.4	72
8.1822	50.0	40.5	9.5	59.4	85
10.0062	50.0	41.0	9.0	56.3	100

Table (XIVB): Toxicity of boric acid against adults of *Blatta orientalis*:

Dose %	Log dose	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
3.6582	0.5633	14	3.90	18	4.10
4.4738	0.6507	27	4.39	32	4.54
5.4711	0.7381	55	5.13	49	4.98
6.6907	0.8255	72	5.58	66	5.41
8.1822	0.9129	85	6.04	80	5.85
10.0062	1.0003	100	-	-	-

: Y= 1.2847+5.0017X Regression equation

: 87 Slope in degrees

: 0.7428 => LD_{50}: 5.5312. LD_{50} Log

Log LD_{95} : 1.0647 => LD_{95}:11.6067.

Variance (V)	: 5.27280^{-4}	
	: 0.0230	Standard Deviation (SD)
	: 0.7428 ± 0.0450.	Log LD 95% fiducial limits

4.2.2.3 Palatability and Toxicity of Natural Plant Products Against Adults of *Blatta orientalis*:

Tables (XVA&XVB) and Figures (11A&11B) show that usher leaves are palatable–and toxic to *B. orientalis*. It is clear that usher leaves dose needed to kill 50% of the population during 24 hours (LD_{50}) is

8.6653% (2.56 ml in 10.24 grams). This mortality takes place after consumption of 10.24 grams of bait containing the above mentioned dose.

When fed on usher whole fruits, LD_{50} is 8.88375% (2.99 ml in 11.89 grams) and the weight corresponding to it is 11.89 grams (Tables XVIA&XVIB and Figures 12A & 12B).

Table (XVA): Palatability of usher leaves to adults of *Blatta orientalis* and resulting mortality.

Dose %	Initial weight g.	Final weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	49.0	33.9	16.0	100	0
4.4563	50.0	36.0	14.0	87.5	10
5.6101	50.0	36.5	13.5	84.4	29
7.0627	50.0	37.9	12.1	75.6	49
8.8914	50.0	39.0	11.0	68.8	67
11.1936	50.0	40.0	10.0	62.5	85
14.0919	50.0	41.0	9.0	56.3	95

Table (XVB): Toxicity of usher leaves against adults of *B. orientalis*

Dose %	Log dose	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
4.4563	0.6490	10	3.72	12	3.82
5.6101	0.7490	29	4.45	27	4.38
7.0627	0.8490	49	4.97	48	4.94
8.8914	0.9490	67	5.44	69	5.49
11.1936	1.0490	85	6.04	85	6.05
14.0919	1.1490	95	6.61	95	6.60

Regression equation : $Y = -0.2149 + 5.5609X$.

: 88. Slope in degrees

: 0.9378 => LD_{50}: 8.6653. Log LD_{50}

Log LD_{95} : 1.2273 =>LD_{95} 16.8774.

Variance (V) : 4.2345×10^{-4}

: 0.0206. Standard Deviation (SD)

: 0.9378 ± 0.0403. Log LD 95% fiducial limits:

Table (XVIA): Palatability of usher whole fruits to adults of *Blatta orientalis* and resulting mortality.

Dose %	Initial weight g.	Final weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	49.8	33.5	16.3	100	0
4.4563	49.8	34.6	15.2	93.3	4
5.6101	49.8	35.1	14.7	90.2	15
7.0627	50.0	36.9	13.1	80.4	32
8.8914	50.0	37.8	12.2	74.8	50
11.1936	50.0	39.0	11.0	67.5	64
14.0919	50.0	39.5	10.5	64.4	89

Table (XVIB): Toxicity of usher whole fruits against adult of *B. orientalis*.

Dose %	Log dose	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
4.4563	0.6490	4	3.25	3.25	3.43
5.6101	0.7490	15	3.96	3.96	3.96
7.0627	0.8490	32	4.53	4.53	4.48
8.8914	0.9490	50	5.00	5.00	5.00
11.1936	1.0490	64	5.36	5.36	5.53
14.0919	1.1490	89	6.23	6.23	6.05

Regression equation : Y=-0.0382+5.2307X.

Slope in degrees : 87.

Log LD_{50} : 0.9486=>LD_{50}: 8.8837.

Log LD_{95} : 1.2564= >LD_{95}: 18.0459.

Variance (V) : $4.55108X10^{-4}$.

Standard Deviation (SD) : 0.0213.

Log LD 95% fiducial limits. : 0.9486±0.0418.

Periplaneta americana: 4.2.3 Palatability and Toxicity of Toxicants Against Adults of

All treated-baits used in this study show potency effects against adults of American cockroaches. Table (XVII) shows the 24 hours LD_{50} with 95% fiducial limits and slope in degrees of tested materials against adults of *Periplaneta americana*. As can be seen in Tables (XVIIIA-XXIIIA) and Figures (13A-18A) increase of toxicant concentration-within certain range-causes only negligible decrease in palatability.

Tables (XVIIIB-XXIIB) and Figures (13B-18B) show the responses of the test animals to the tested baits.

4.2.3.1 Palatability and Toxicity of Insecticides Against Adults of *Periplaneta americana:*

Palatability and LD_{50} of propoxur and malthion are shown in Tables (XVIIIA-XIXA& XVIIIB-XIXB), and Figures (13A-14A &13B-14B) respectively. Palatability of propoxur is 14.63 grams and its LD_{50} is 1.0544% (3.65 ml in 14.63 grams) while palatability of malathion is 14.04 grams and its LD_{50} is 3.3270% (3.51 ml in 14.04 grams).

4.2.3.2 Palatability and Toxicity of Chemical Compounds Against Adults of *Periplaneta americana*:

Tables (XXA & XXB) and Figures (15A&15B) show that sodium fluoride is palatable by- and toxic to *P. americana*. It is clear that sodium fluoride dose needed to kill 50% of the population during 24 hours (LD_{50}) is 7.2029% (3.90 ml in 15.58 grams). This mortality takes place after the consumption of 15.58 grams of bait containing the above mentioned dose When fed on boric acid, LD_{50} is 8.3022% (3.99 ml in 15.98 grams) and the weight corresponding to it is 15 98 grams (Tables XXIA&XXIB and Figures 16A&16B).

Table (XVII): The 24-hours LD_{50} with fiducial limits of the tested materials aqueous extracts treated baits against adults of *Periplaneta americana*

Toxicant	LD_{50}% (W/V)			Slope in degrees
	Upper limit	Average	Lower limit	
Propoxure	1.2425	1.0544	0.8947	81
Malathion	3.7489	3.3270	2.9532	85
Sodium fluoride	7.7983	7.2029	6.6527	89
Boric acid	9.1348	8.3022	7.5457	87
Usher leaves	9.3994	8.5216	7.7250	87

Usher whole-fruits	10.8118	9.7302	8.7559	86

Table (XVIIIA): Palatability of propoxur to adults of *Periplaneta americana* and resulting mortality.

Dose %	Initial weight g.	Final weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	49.9	30.9	19.0	100	0
0.2600	49.9	32.9	17.0	89	4
0.4329	49.0	33.4	16.5	86.8	12
0.7211	50.0	34.2	15.8	83.0	30
1.5497	50.0	35.1	14.9	78.4	62
1.7605	50.0	36.5	13.5	71.1	75

2.0000	50.0	38.0	12.0	63.2	86

Table (XVIIIB): Toxicity of propoxur against adults of *P. americana.*

Dose %	Log dose + 1	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
0.2600	0.4150	4	3.25	2	3.05
0.4329	0.6365	12	3.82	11	3.67
0.7211	0.8580	30	4.48	29	4.47
1.5497	1.1903	62	5.32	70	5.52
1.7605	1.2456	75	5.67	76	5.71
2.0000	1.3010	86	6.08	82	5.9

Regression equation : Y =-1.7231 +3.2032X.

Slope in degrees : 81.

Log LD_{50} : 1.0230=>LD_{50}: 1.05441.

Log LD_{95} : 1.5256= >LD_{95}: 3.3545.

Variance (V) : 1.3218×10^{-3}.

Standard Deviation (SD) : 0.0364.

Log LD 95% fiducial limits. : 1.0230± 0.0713.

Table (XIXA): Palatability of malathion to adults of *Periplaneta americana* and resulting mortality.

Dose %	Initial weight g.	Final weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	50.0	30.5	19.5	100	0
2.0000	50.0	33.5	16.5	84.6	20
2.8284	50.0	35.0	15.0	76.9	36
3.3635	50.0	35.8	14.2	72.8	50
4.0000	50.0	36.9	13.1	67.2	65
5.6568	50.0	38.0	12.0	61.5	79
6.7271	50.0	39.0	11.0	56.4	92

Table (XIXB): Toxicity of malathion against adults of *P. americana*.

Dose %	Log dose	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
2.0000	0.3010	20	4.16	18	4.10
2.8284	0.4515	36	4.64	39	4.71
3.3635	0.5267	50	5.00	51	5.02
4.0000	0.6020	65	5.39	63	5.33
5.6568	0.7525	79	5.81	83	5.95

6.7271	0.3278	92	6.41	89	6.25

Regression equation Y = 2.8590 +4.1011X.

Slope in degrees : 85.

Log LD_{50} : 0.5221=>LD_{50}: 3.3270.

Log LD_{95} : 0.9146= >LD_{95}: 8.2151.

Variance (V) : $6.9917X10^{-4}$.

Standard Deviation (SD) : 0.0264.

Log LD 95% fiducial limits. : 0.5221± 0.0518.

Table (XXA): Palatability of sodium fluoride to adults of *Periplaneta americana* and resulting mortality.

Dose %	Initial weight g.	Final weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	50.0	31.0	19.0	100	0
4.5715	50.0	32.5	17.5	92.1	12
5.5903	50.0	33.1	16.9	88.9	27
6.8359	50.0	34.0	16.0	84.2	46
8.3593	50.0	34.6	15.4	81.1	60
10.2221	50.0	35.8	14.2	74.7	78
11.3038	50.0	36.9	13.1	68.9	91

Table (XXB): Toxicity of sodium fluoride against adult of *P. americana:*

Dose %	Log dose	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
4.5715	0.6601	12	3.82	12	3.80
5.5903	0.7474	27	4.39	25	4.33
6.8359	0.8348	46	4.90	45	4.86
8.3593	0.9222	60	5.25	65	5.39

10.2221	1.0095	78	5.77	82	5.92
11.3038	1.0532	91	6.34	88	6.19

Regression equation : Y = -0.1940 +6.0572X.

Slope in degrees : 89.

Log LD_{50} : 0.8575=>LD_{50}: 7.2029.

Log LD_{95} : 1.1233=>LD_{95}: 13.2821.

Variance (V) : 3.1050×10^{-4}.

Standard Deviation (SD) : 0.0176.

Log LD 95% fiducial limits. : 0.8575±0.0345.

Table (XXIA): Palatability of boric acid to adults of *Periplaneta americana* and resulting mortality.

Dose %	Initial weight g.	Final weight g.	Consumed weight	Consumed weight %	Mortality %
0.0000	49.9	30.9	19.0	100	0
5.4711	49.9	31.9	18.0	94.7	15
6.6907	49.9	32.6	17.3	91.1	34
8.1822	50.0	33.8	16.2	85.3	54
10.0062	50.0	34.3	15.7	82.6	65
12.2369	50.0	35.0	15.0	78.9	75
14.9648	50.0	35.5	14.5	76.3	92

Table (XXIB): Toxicity of boric acid against adults of *P. americana*

Dose %	Log dose	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
5.4711	0.7381	15	3.96	18	4.09
6.6907	0.8255	34	4.59	32	4.53
8.1822	0.9129	54	5.10	49	4.97
10.0062	1.0003	65	5.39	66	5.41
12.2369	1.0877	75	5.67	80	5.84

14.9648	1.1751	92	6.41	90	6.28

Regression equation : Y = 0.4026+5.0016.

Slope in degrees : 87

Log LD_{50} : 0.9192=>LD_{50}: 8.3022.

Log LD_{95} : 1.2411= >LD_{95}: 17.4235.

Variance (V) : 4.4852×10^{-4}.

: 0.0212. Standard Deviation (SD)

Log LD 95% fiducial limits. : 0.9192±0.0415.

Adults of *Periplaneta americana:* 4.2.3.3 Palatability and Toxicity of Natural Plant Products Against

When known concentrations of usher leaves and usher whole fruits were used against *P. americana*, palatability values (the consumption weight during 24 hours) were 16.58 grams and 16.97 grams respectively and their

LD_{50} values were 8.5216% (4.14 ml in 16.58 grams) and 9.7302% (4.24 ml in 16.97 grams). These are shown in Tables (XXIIA-XIIIA &XXIIB-XXIIIB) and Figures (17A-18A &17B-18B).

Table (XXIIA): Palatability of usher leaves to adults of *Periplaneta americana* and resulting mortality.

Dose %	Initial weight g.	Final weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	49.8	30.3	19.5	100	0
5.0000	49.9	31.8	18.1	92.8	15
6.2947	50.0	32.5	17.5	89.7	25
7.9247	50.0	33.0	17.0	87.2	45
9.9763	50.0	33.5	16.5	84.6	60
12.5595	50.0	34.1	15.9	81.5	75
15.8114	50.0	35.1	14.19	76.4	93

Table (XXIIB): Toxicity of usher leaves against adults of *P. americana*.

Dose %	Log dose	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
5.0000	0.6990	15	3.96	13	3.87
6.2947	0.7990	25	4.33	26	4.36
7.9247	0.8990	45	4.87	44	4.85
9.9763	0.9990	60	5.25	63	5.33
12.5595	1.0990	75	5.67	79	5.82
15.8114	1.1990	93	6.48	90	6.31

Regression equation : $Y = 0.4630+4.8758X$.

Slope in degrees : 87

Log LD_{50} : $0.9305 = > LD_{50}: 8.5216$.

Log LD_{95} : $1.2607 => LD_{95}: 18.2250$.

Variance (V) : 4.7163×10^{-4}.

Standard Deviation (SD) : 0.0217.

Log LD 95% fiducial limits. : 0.9305 ± 0.0426.

Table (XXIIIA): Palatability of usher whole-fruits to adults of *Periplaneta americana* and resulting mortality.

Dose %	Initial weight g.	Final weight g.	Consumed weight g.	Consumed weight %	Mortality %
0.0000	50.0	30.5	19.5	100	0
5.0000	50.0	31.5	18.5	94.9	10
6.2947	50.0	32.0	18.0	92.3	20
7.9245	50.0	32.6	17.4	89.2	35
9.9763	50.0	33.0	17.0	87.2	50
12.5595	50.0	33.3	16.7	85.6	66
15.8114	50.0	34.0	16.0	82.1	86

Table XXIIIB Toxicity of usher whole fruits against adults of *P. americana*

Dose %	Log dose	Empirical mortality		Calculated mortality	
		%	Probit	%	Probit
0.0000	0.0000	0	-	-	-
5.0000	0.6990	10	3.72	9	3.69
6.2947	0.7990	20	4.16	19	4.14
7.9245	0.8990	35	4.61	35	4.60
9.9763	0.9990	50	4.92	52	5.05
12.5595	1.0990	66	5.41	69	5.50
15.8114	1.1990	86	6.13	83	5.95

Regression equation : $Y = 0.5313 + 4.5225X$.

Slope in degrees : 86.

Log LD_{50} : 0.9881 =>LD50: 9.7302.

Log LD_{95} : 1.3441 = >LD95: 22.0871.

Variance (V) : 5.4517×10^{-4}.

Standard Deviation (SD) : 0.0233.

Log LD 95% fiducial limits. : 0.9881 ± 0.0458.

CHAPTER FIVE

DISCUSSION

In spite of the fact that Sudan is a tropical country where cockroaches are very abundant, their medical importance is not fully appreciated by many citizens. The present work was carried out to study the hygienic importance of the Sudanese cockroaches *Blattela germanica*, *Blatta orientalis* and *Periplaneta americana* as mechanical transmitters of pathogenic bacteria. Most people have the general impression that these insects live and thrive in dirty places and, in some way, are connected to diseases. However, there is a strong relation between these insects and the many pathogenic bacteria they transmit.

Although the present investigation does not cover anaerobic bacteria, it indicates that several serious, disease –causing bacteria are carried and transmitted by cockroaches. The situation is aggravated by the low sanitary conditions that prevail in most parts of the Sudan. In the present investigation more species of Gram-negative bacteria were isolated than Gram-positive bacteria. Most of the bacteria isolated were found to belong to three families Micrococcaceae, Enterobacteriaceae and Pseudomonadaceae.

The present work shows that cockroaches in Sudan are heavily infested with several pathogenic bacteria. These include: *Klebsiella pneumonia, Serratia* spp., *Salmonella* spp., *Shigella* spp., *Escherichia coli, Proteus mirabilis, Enterobacter gergoviae*, *Staphylococcus aureus* and *Pseudomonas fluorescens* (Appendix IV). Herms and Nelson (1913), by means of simple bacteriological experiments, showed that *Blattela germanica* can aquire bacteria by crawling over cultures and then depositing the bacteria on food.

Several researchers isolated pathogenic bacteria from *Blattela germanica*, *Blatta orientalis* and house flies (Longfellow, 1913; Cao, 1898,1906a,b;

Ficker, 1903; Hamilton, 1903; Graham-Smith, 1909; Ledingham, 1911; Nicoll, 1911; Herms, 1939).

Records of the Ministry of Health of Khartoum State show high numbers of cases. In the year 2001: 298383 cases of pneumonia, 175945 cases of diarrhoea, 171674 cases of urinary infections, 72834 cases of dysentery, 21054 cases of abscesses, 16064 cases of typhoid and 3795 cases of food poisoning were recorded (Anon, 2001). Most of these cases resulted from water and food contamination. They are associated with low standards of personal and public hygiene.

Cockroaches are comparable to house flies in transmitting pathogenic diseases to man. However, very few people are aware of the harm caused to their health by cockroaches. This can, at least in part, be attributed to the fact that the house flies are active fliers the activity of which attracts our attention unlike cockroaches which are silent creepers. The most disgusting and potentially dangerous feature of cockroaches behaviour are their habits of regurgitating some of their partially digested food and dropping faeces, often at the same time as they are feeding.

The prevalence of bacterial diseases in the Sudan and the role of cockroaches in spreading these diseases stimulated the present work. There is an urgent need to suggest control methods by which cockroach population can be suppressed. The aim of this part is to find out low-risk, practical and economical means of control.

The evaluation of the impact of an insecticide must take into consideration its toxicity to target organisms and non-target organisms, human safety, and cost.

In the present study an attempt was made to build upon these aspects and investigate the applicability of using baits which contain toxicant agents. The materials chosen in this study were two chemical insecticides (propoxur and malathion), two chemical reagents (sodium-fluoride and boric acid) and natural plant products (usher leaves and usher whole fruits). In Third World conditions better outcome is expected if 'appropriate technology' is employed.

The fact that increase of toxicant concentration does not cause large decreases in palatability, and that mortality increases linearly with concentration suggests that quite high concentration of toxicants leading to high mortality can be used. Adult mortality increased as the concentration of the extracts increased from 4.4563% to 22.3342%.

The results indicate that all agents studied were palatable to the insects. These, arranged in a descending order of palatability, were natural products, chemical reagents and chemical insecticides.

The present results conform with those of Sharma (1983) who offered usher to the adults of *Rhizopertha dominica* and concluded that the plant was without antifeedant effect and was palatable to the insects. Usher leaves aqueous extracts treated food and usher whole fruits aqueous extracts treated food in this study were palatable by adult cockroaches. This opens a door to use these extracts of the plant in cockroach control. Ahmed (1993) and Osman (1999) reported that sodom apple, powder and extracts had repellent activity against storage pests.

Baits to which chemical compounds (sodium fluoride and boric acid) and chemical insecticides (propoxur and malathion) were incorporated

were offered to cockroaches. Sodium fluoride, boric acid and malathion were employed as spray and dust formulation in cockroach control (Wright & Hillman, 1973; Wright, 1982) but in the current study they are used as bait formulation.

The consumption of baits taken by cockroaches decreased slightly with increasing concentration of the test agents. Considerable variations in palatability of treated baits were noticed. *Periplaneta americana* consumed high amounts, followed by *Blatta orientalis* and then *Blattela germanica.*

In the current investigation, all treated baits showed insecticidal activities against cockroaches. Arranged in a descending order of toxicity they were: propoxur, malathion, boric acid, sodium fluoride, usher leaves and usher whole-fruits.

According to WHO (1984) the use of chlorinated hydrocarbons against cockroach was abandoned and the recommended insecticides are carbamates and organophosphoates.

In the present study the 24 hours LD_{50} values of propoxur-bait against adults of *Blattela germanica, Blatta orientalis* and *Periplaneta americana* were 1.424% (1.16 ml in 4.65 grams), 0.8583% (2.48 ml in 9.90 grams) and 1.0544% (3.65 ml in 14.63 grams) respectively.

Malathion bait gave 24 hours LD_{50} value against adult of German, oriental and American cockroaches, of 3.6314% (1.23 ml in 4.9 grams), 3.4324% (2.20 ml in 8.80 grams) and 3.3270% (3.51 ml in 14.04 grams) respectively.

The sensitivity of the three cockroach species to insecticide-decreases in the order oriental, American and German cockroaches.

Wright and Hillman (1973), and Wright (1982) reached similar conclusions using sodium fluoride and boric acid as dusts. They conclude that dusts of 1% sodium fluoride and boric acid are occasionally employed in cockroach control. In the current study considerable variations in potency were noticed with sodium fluoride followed by

boric acid. The LD_{50} of sodium fluoride against German, oriental and American cockroaches were 8.2916% (1.85 ml in 7.41 grams), 4.8955% (2.44 ml in 9.76 grams) and 7.2083% (3.90 ml in 15.58 grams) respectively. The LD_{50} values of boric acid were lower than that of sodium fluoride. These are 10.9802% (2.77 ml in 11.08 grams), 5.5312% (2.76 ml in 11.04 grams) and 8.3022% (3.99 ml in 15.98 grams) respectively. The sensitivity of the three cockroach species to sodium fluoride and boric acid is in the order oriental, American and German cockroaches.

The above results seem that to kill cockroaches higher concentrations of sodium fluoride and boric acid are needed when the chemical is incorporated in baits than they are used as dusts.

Integrated Pest Control (IPC) programs involve the use of natural products. The plant kingdom has provided many remedies for human health problems, including antibiotics, muscle relaxant, anti malaria drugs and morphine (Bashir, 1980). Plant products are preferred by (IPC) programs over synthetic chemicals for the control of disease vectors. This is because plant products are naturally abundant, easy to prepare, safe and have no hazard to the environment. In the current investigation the efficiency of a widely spread plant in Sudan (sodom apple) was tested against cockroaches. The study shows that both leaves and whole fruits of sodom apple are toxic against cockroaches and significant mortality cases ranging from 5% to 94% were noticed. Ali (1999) reported that prolonged feeding on usher leaves water extract treated food resulted in significant death rate of insects and all death cases occurred during the immature stages of the desert locust.

The antifeedant, growth regulatory and insecticidal activities of usher extracts were reported against *Rhziopertha domincia, Trogoderma granarium, Bruchidius incarnatus* (Sharma, 1983, 1985; Ahmed, 1993; Osman 1999; Jacob and Sheila, 1993; Wat, *et al* 1962).

In the present study, usher leaves aqueous extracts treated food was used for the control of the adult cockroaches, and showed potency comparable to that of usher whole fruits aqueous extract treated food. Ali (1999) reported that the presence of plant extract in the locust food resulted in decreased intake and/or utilization of food and death could result from poisoning, starvation or combination of both.

Generally speaking, the oriental cockroaches are more sensitive to the test agents followed by the American cockroach and then the German cockroaches.

The investigated plant showed noticeable activity against cockroaches, hence, they would make a good candidate for natural control agents to be employed in Integrated Pest Control programs.

CONCLUSION AND RECOMMENDATIONS

The output of this work can be summarized as follows:

Cockroaches are hygienically notorious insects transmitting several human diseases. Awareness of this and similar problems should encourage people to avail work for laboratory research and pilot experiments leading to the actual application of research results. Since usher plant proved to be palatable by and poisonous to cockroaches, our recommendation is to use usher extract impregnated baits to control these insects.

The current study may be further improved by refining extraction and application procedures. Field evaluations of treated-baits against cockroaches deserve further studies. Stability of natural products tested under field conditions is of equal significance and must be considered in any future line of research.

CONCLUSION

1- Bacteriological studies showed the hygienic importance of Sudanese cockroaches as mechanical vectors of pathogenic bacteria such as *staphylococcus aureus, Salmonella spp. shigella spp. Klebsella preumoniu*, *Serritia marcescens, Entero bacter spp, Proteus mirabilis, Escjerichia coli* and *Pseudomonas spp.*

2- The number of bacterial species infecting adult of *Periplaneta americana* was more than that isolated from adult of *Blatta orientalis*, followed with adult of *Blattela germanica.*

3- All test agents showed insecticidal activities against test insects with propoxur > malathion > sodium fluoride >boric acid >usher leaves >usher whole-fruits.

4- All treated baits showed palatability to test insects with Usher whole-fruits > Usher leaves >Boric acid >sodium floride .Propoxur>Malathion.

5- The sensitive of cockroaches to the tested agents were *Blatta orientalis >Periplaneta americana >Blattela germanica.*

6- The palatability of cockroaches to the tested agents were *Periplaneta americana > Blatta orientalis > Blattela germanica*.

RECOMMENDATIONS

1- For the purpose of isolation of pathogenic bacteria cockroaches will be collects from different sites around Khartoum State.

2- Bacterial species will be isolated from eggs, nymph, adult males and adult females of cockroaches.

3- The techniques use will be suit the isolation of anaerobic bacteria and more Gram-positive and-negative bacteria.

4- For the purpose of control of cockroaches, facilities to breed this insect in the section laboratories should be made available.

5- To facilitative the evaluation of usher latex for the control of cockroaches, efficient methods of collecting usher latex should be developed.

6- Best evaluation of efficiency of the treated baits studied could be obtained at longer intervals after 24 hours.

7- Cockroach control or suppression programmes should be organized on at least a community –wide scale. The initial efforts should be directed at careful surveys and appraisals of existing cockroach problems, including reservoir populations. After the problem is thoroughly under stood, effort s should be made to organize educational programmes designed to inform the citizens of their local situation and the importance of cockroaches in health and the quality of the environment. As this is being accomplished, citizens

should be aided and encouraged to reduce or eliminate cockroach harborage sites, carry out cockroach exclusion measures and improve environmental sanitation procedures in both individual living space and in public areas. Finally, control procedures involving the use of chemical insecticides and other methods should be undertaken.

CHAPTER SIX
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APPENDIX

Appendix I: Composition of the Reagents.

1- Sodium chloride medium, 5ml (8.5 gram of NaCl in 1000ml water).
2- TDA reagents, 5ml (3.4gram of ferric chloride in 100 ml water)
3- JAMES reagent, 5ml (0.5 gram compound J 2183 (confidential) in 100 ml HCl 1N).
4- VP1 reagent, 5ml (40 gram of potassium hydroxide in 100ml water).
5- VP2 reagent, 5ml (6 gram of α-naphthol in 100ml ethanol).
6- NIT1 reagent, 5ml (0.4 gram of sulfanilic acid and 30 gram of acetic acid in 70ml water).
7- NIT2 reagent, 5ml (0.6 gram of N,N-dimethyl-1-naphylamine and 30 gram of acetic acid in 70ml water).
8- Zinc reagent, 10 gram (Zinc dust).

Appendix (IV) The Medical Importance of Isolated Species

Isolated species	*Main medical importance
Staphylococcus aureus	Abscesses, boils, wound, pneumonia and flood poisoning
Escherchia coli	Diarhoeal disease, urinary infections and bacteraemia
Klebsiela pneumoniae	Chest infections, urinary infections, would infections, and bacteraemia
Shigella spp.	Bacillary dysentery and bacteraemia
Proteus mirabilis	Urinary infections, bacteraemia, wound infection and chest infections.
Serratia spp.	Pulmonary and urinary infections
Salmonella spp.	Enteric fever, food poisoning, bone infections and abscesses
Enteropacter gergoviae	Urinary infections, septicaemia and wound infections.
Pseudomonas fluorescens	Skin infections, urinary infections, respiratory infections and external ear infections.

* Cited by cheesbrough, 1991.