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THE ANIMAL IN THE LENS OF A ZOOLOGIST

By

Professor Adewumi Babatunde Idowu,
(Professor of Zoology)

Department of Pure and Applied Zoology
College of Biosciences (COLBIOS)
Federal University of Agriculture, Abeokuta, Nigeria

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Professor Adewumi Babatunde IDOWU
(B. Sc. (Ado-Ekiti) M.Sc, Ph.D(Ibadan)
(Professor of Zoology)

THE ANIMAL IN THE LENS OF A ZOOLOGIST

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Members of my Immediate and Extended Families,
Friends of the University/ Special Guests,
Fellow Scholars,
Gentlemen of the Press,
Distinguished Ladies and gentlemen,
Great FUNAABITES

1.0 INTRODUCTION

It is indeed a great honour to be called upon to deliver the first inaugural lecture from the new College of Biosciences, the first from the Department of Pure and Applied Zoology, the 50th in the University coming shortly after my 50th birthday which by the grace of God I celebrated on January 3rd 2015, a testimony to the fact that indeed God orders the steps of His beloved ones. I am indeed delighted that we now have a Department of Pure and Applied Zoology several years after we sought for it and two colleges, the College of Biosciences and College of Physical Sciences created out of the College of Natural Sciences. We thank God for using our amiable Vice-Chancellor, Prof. Olusola Bandele Oyewole in this regard.

Prof. Afolabi Toye of blessed memory proferred that an inaugural lecture is an academic exercise providing an opportunity for a person to briefly review his own research field, explain what his contributions were all about and to assess their relevance or otherwise to the aspirations of socio-economic upliftment of the society to which he/she belongs. I will anchor mu inaugural lecture on this premise and hope ro embody in it my personsl philosophy.

Mr Vice-Chancellor, Sir, in the beginning, while a student in 1982 at the then Obafemi Awolowo University, Ado-Ekiti, which name changed severally to now Ekiti State University, I

was excited in subjects which include invertebrate zoology, entomology, parasitology, animal physiology, human genetics and their practical classes. The excitement was an expression of my innate desire to study animals. The concept of about zoology as a course, its potential and significance in nation building especially in Nigeria is still not properly understood by many people in the society including the students of the department of zoology. It is my hope that the misconceptions of the subject will be addressed in the lecture titled **"The Animal in the lens of A Zoologist"**

2.0. ZOOLOGY AS A COURSE

What is Zoology? In simple English, it is the study of animals and more than that, it is scientific study of animals. A zoologist is therefore a person who is involved in the scientific study of animals.

2.1. WHAT DO WE TEACH

The animal world as seen by a zoologist extends from the simplest animal the Protozoa to the most complex, Mammals. Figure 1 shows the array of animals that a zoologist in the making is introduced to during his undergraduate years. The diversity in each phylum is so vast and complex to teach and understand but the reality of seeing the representatives of the animals in the practical classes helps to easily unravel the mystery behind the complexity. I am sure the the Vice-Chancellor

will now appreciate the justification by the Department for additional funds every year to acquire new set of specimens for the Department. The listed subjects below as contained in the curriculum of my Department approved by the University Senate allow us to provide judicious opportunity for our students to understand the animal world during their four years stay in the University.

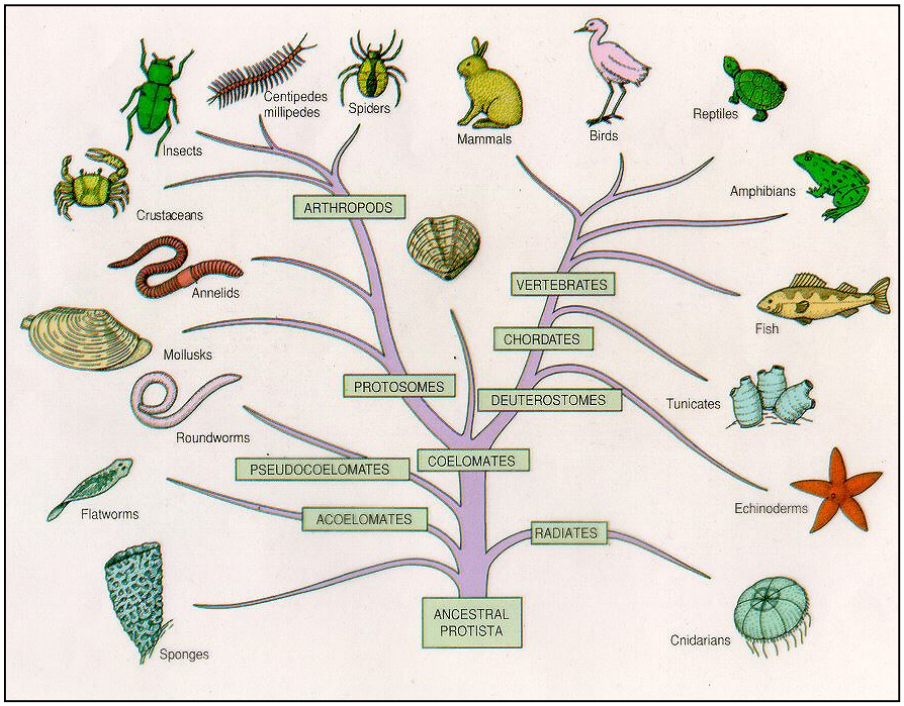


Figure 1: Phylogenetic tree of the animal kingdom Source: http://www.glogster.com/evvem/animals/g-6lmc6jkr0i9jrvc9mgfqda0

Zoogeography, also known as *descriptive zoology*, describes animals and their habitats

Systematic zoology Scientific classification in zoology, is a method by which zoologists group and categorize organisms by biological type, such as genus or species. Biological classification is a form of scientific taxonomy.

Comparative anatomy studies the structure of animals
Comparative Animal physiology, analysis of functions in animals

Ethology, study of animal behaviour

Invertebrate zoology, a study of the lower animals from protozoa to echinoderms

Vertebrate zoology, study of the animals with vertebrate

Histology, study of tissues

Embryology, study of development of embryos

Evolutionary Studies

Limnology and fisheries

Entomology, study of Insects

Parasitology, study of disease causing organisms

Ecology, study of the relations of animals and plants in relation to their surroundings

Genetics, study of heredity and variation; of the resemblances and differences between organisms and

Business Opportunities in Zoology

Many zoologists in later years at postgraduate level are identified by the types of species they study

Entomologists study insects.

Herpetologists study reptiles and amphibians, such as snakes and frogs.

Ichthyologists study fish***.***

Mammalogists study mammals, such as monkeys and bears.

Ornithologists study birds.

Marine biologists study organisms that live in saltwater.

Limnologists study organisms that live in freshwater.

Ecologists study the ecosystem, which is the relationship between organisms and with the surrounding environment.

Evolutionary biologists study the origins of species and the changes in their inherited characteristics over generations.

Others are identified by the aspects of zoology they study, such as parasitologist, animal physiologist, geneticist, ecologist and ethologists.

The field of zoology is a very diverse field that the training received has enabled students with a degree in Zoology to pursue careers in human and veterinary medicine, environmental monitoring and regulation, scientific research and development, education, animal and crop production and protection, crude oil exploration to mention a few. But in recent times, we have lost some of our best students to banks, accounting firms and some unrelated fields of science and this is not too good for the science of zoology.

Of all the areas of specialization in zoology, animal physiology appears to be one of the least attractive to students. To

excel in animal physiology, the student must be in love with chemistry, biochemistry and also have understanding of some basic principles of mathematics and physics. Most students offering zoology as their major will rather prefer to relate with these subjects from afar off and this seems to me to be the major reason why students are weary of this area of specialization in zoology. The biology of any animal is not complete without a thorough understanding of its physiology. It is sad to say that the physiology of most of the already identified Nigerian fauna is still vague.

2.2 MAJOR CONSTRAINT IN THE TEACHING OF ZOOLOGY IN NIGERIA

It is also note worthy to mention here that the lack of Nigerian specimens is one major constraint in the teaching of zoology in higher institutions. We still depend mostly on foreign species in practical classes and even as example in textbooks authored by Nigerians. It is a major task that will need government motivation and support.

3.0. THE JOURNEY INTO ANIMAL PHYSIOLOGY

My motivation for animal physiology started as a young boy who was always fascinated by the transformation of the ever white pounded yam into brownish materials as it comes out of my anus. I was curious to know what was causing the transformation as it rolls down my pharynx into the other part of

the digestive system for processing before it comes out of my anus. At the then Ondo State University, the teachings of Prof. Oduleye of University of Ilorin and the then Dr. M.O. Onagbesan (Linea Alba) further propel my interest in the subject despite its complexity. While discussing my final year project with me, my B.Sc supervisor Late Prof VLO Yoloye, a man of great passion for his job asked me what I will be doing after my B.Sc programme. I told him I like to specialise as an animal physiologist. He was so excited about my desire and emphasised how rarely students show interest in this area of specialization.

3.1 What is Animal Physiology? The science of physiology is the analysis of function in living organisms (Schmidt-Nielsen, 2007). One of the pre-requisites for its study is knowledge of morphology. Physiology is a synthetic science which applies physical and chemical methods to biology. In a plain language, animal physiology is about- how they eat, breathe, and move about, and what they do just to keep alive. Physiology is also about how the living organism adjusts to the adversities of the environment-obtains enough water to live or avoids too much water, escapes predation(another animal eating it), moves about to find suitable surroundings, food, and mates- and how it obtains information about the environment through its senses. Finally, physiology is about the regulation of all these functions- how they are correlated and integrated into a smooth-functioning organism (Schmidt-

Nielsen, 2007).

3.2. **The Ideal Relationship between departments using animals for their research**

Physiology is such a diverse subject that if care is not taken could cause division among the practitioners as it was in the case between those of us in the then Department of Biological Sciences and others in College of Animal Science of the Federal University of Agriculture, Abeokuta (FUNAAB). May I seek the permission of the Vice-Chancellor to speak a little about this before moving forward? For those of us in Pure and Applied Zoology, physiology is more of comprehensive exploratory study of all animals excluding human being as against definite experimental study of food animals in Animal Science. The Veterinary Scientists are more interested in the study of domesticated and recreational animals. The figure 2 may also help to explain the different perspective. Prof. Olusegun Osinowo will bear me witness that even from our studies on snail and publications thus far, there seems to be a parallel line in our concept and direction as animal physiologists. While we are exploring the animals for basic information with a broader aim of having a total understanding of their quality of life, the animal scientists are after how best to present the animal at the dinning table. Mostly scientists create ideas inform of hypothesis and theories. These ideas are utilised by technologists (applied scientists) in producing things. I am not

sure that this concept is really exploited in Nigeria for national development.

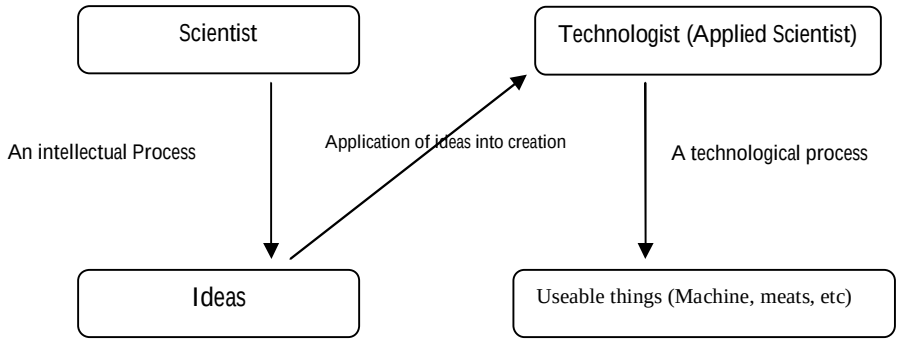
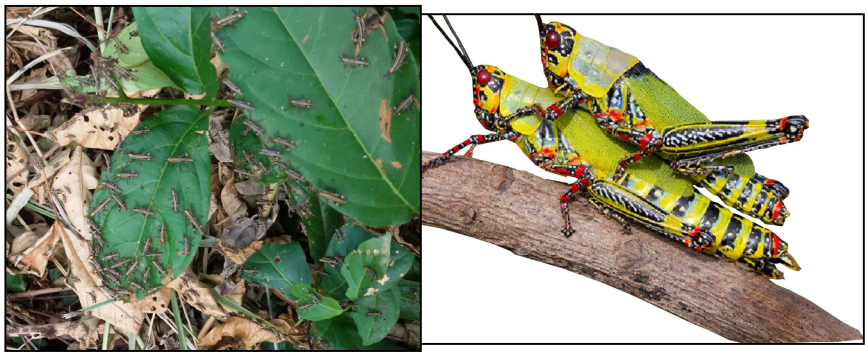


Figure 2: The ideal Relationship between science and applied science (technology)

4.0 MY CONTRIBUTIONS TO ANIMAL PHYSIOLOGY



Nymphal and adult instars of Zonocerus variegatus

The *Zonocerus* Invasion Ecc*. 12:5..... and the grasshopper shall be a burden*

As a preamble to enumerating my contributions to the body of knowledge on the physiology of *Zonocerus*, let me quote some parts of Prof. Afolabi Toye's presidential speech delivered to the annual conference of the Entomological Society of Nigeria at the University of Ife in September, 1973

"One of the major insect pests constantly mentioned in literature in Nigeria is *Zonocerus variegatus*. As far back as 1911, Peacock observed the species to be a notorious pest of many food and economic crops in Nigeria..... I observed a very large population of *Z. variegatus* damaging a banana plantation in the Okemesi area of the western state of Nigeria. Since then I have carried out a series of investigation into the biology of the species. Among the valuable information so far obtained is that the early larval stages (notably the first, second and third) feed exclusively on weeds such as *Eupatrium odoratum* (now *Chromolaena odorata*), *Aspilia latifolia*, etc. The severe attacks on cassava, citrus and banana often conspicuous in the field in January, February and March are caused by the more advanced instar larvae and adults. I have also postulated the idea that rapid spread in recent years of *E. odoratum* in the southern areas of Nigeria may account for the ever increasing abundance of the *Z. variegatus* and the consequent severity in the damage caused to crops. Such is the magnitude and com-

plexity of the problems caused by *Z. variegatus* as an insect pest of economic importance in Nigeria that the British Government (through the overseas Development Administration) and the Federal Military Government have financially agreed to sponsor a joint research programme with a view to designing effective integrated control measures against the pest".

The Centre for Overseas Pest Research (COPR), London led by Prof. R.F. Chapman eventually submitted its final report in 1977. Their work produced quite a number of publications which have been of tremendous benefits to researchers, lecturers and students interested in the biology of *Z. variegatus*. It seems to me that the initiation for the project on *Zonocerus* came from the British and not Nigeria because ever since the Nigerian government to the best of my knowledge seems unconcerned about the activities of this variegated grasshopper. I have not seen a white paper emanating from the Nigerian government on this report but the British government has a position paper on this project.

Chapman *et al* (1986) in their review on the bionomics of the variegated grasshoppers made two concluding remarks which are very important to this discourse namely, (1) relatively few studies have been made on the physiology of *Z. variegatus* (2) there are still large gaps in our knowledge of *Z. variegatus* and probably the most important is the proper evaluation of the

pest status of the insect.

Although, the African grasshopper *Z. variegatus* was given a pest status in 1970 by the National Agricultural Technical Committee because of the increase in its number, my work on Zonocerus commenced shortly after the publication of the great review on the bionomics of Zonocerus by Chapman *et al* (1986) and it was a great pleasure to receive a letter from Prof. R.F. Chapman along some of the reprints of his publication acknowledging my effort in filling some of the missing gaps on the physiology of the African grasshopper. I am not too sure that the reports of the extensive work done by the group and those of us who have continued thereafter have benefitted the Nigerian farming system, thereby leading to less stress for farmers and abundance of food. *Zonocerus* is still the same story, a major economic pest of crops in Nigeria today.

Why has the influence of this grasshopper in particular remain the same despite all our activities in the laboratory of most universities offering Zoology in Nigeria? The conclusion of the matter is lack of proper coordination between the scientists either in the laboratory or field and the applied scientists who are in contact with the farmers who bears the brunt of this pest. Who do we hold responsible for this failure or irresponsibility.

4.1 My contributions on the physiology of *Zonocerus variegatus*

4.1.1 *Zonocerus variegatus* and its survival strategies: Studies on the Structure of its Repellent Gland

The African grasshopper, *Zonocerus variegatus* (L) is known for a strong and offensive body odour which has its origin in a repellent gland which is situated on the 1st and 2nd abdominal segments (Figure 3). It is present in all the instars but only opens to the outside in the 3rd and latter instars (Idowu, 1995). Histological studies showed secretory granules in the cytoplasm of the secretory cell of the gland from the 3rd instar upward and so also was the presence of secretion in the gland lumen (Idowu, 1995). Thus, based on these evidences, the gland becomes functional at the third instar. The great majority of the defensive glands in arthropods are integumental organs arising as unfolding of the body wall (Whitman, 1990). Typically, a gland is made up of a sacklike reservoir in which the secretion is stored, and a secretory tissue that may be part of the wall of the reservoir joined to it by one or more special ducts.

In adult *Zonocerus*, the gland maximum dimensions are length 5.9mm, width 3.8mm, volume 225mm^3, orifice diameter 1.1mm (Table 1). The wall of the gland consists of (i) a luminal cuticular lining (ii) an epithelial layer consisting mostly of secretory cells and fewer non-secretory cells (iii) a base-

ment membrane (Plate 1a and Table 2). The nuclei of the secretory cells are spherical and ovoid in shape and surrounded by many secretory granules. The non-eversible, cuticle-lined gland lumen functions as a reservoir. The intima and the epithelium are continuous with the cuticle and the epidermis of the integument showing that the gland is an invagination of the body wall (Plate 1b).

The gland is dorso-ventrally flattened (Figure 2) when empty but bulbous or ovoid in shape when filled with fluid. The gland wall is brown in colour and makes the gland to stand out from all other internal structures of the grasshopper. Through the transparent wall, a foamy –crystal like secretion may be observed in the gland lumen when viewed under the microscope. The gland lumen is very spacious (R in plate 1) and serves as the gland reservoir. The volume of the gland lumen ranged from $6mm^3$ in the first instar to $225mm^3$ in the adult instar (Table 1)

Further studies revealed that the size of the gland and that of its secretory cells, the space it occupied in the insect body as well as the supply of tracheal endings to the gland increases progressively following each moult (Figure 4). Although the growth relationship between the insect body and gland length is disproportional or allometric, a positive correlation exists in the growth (Figure 5). One of the implications of the increas-

ing size of the gland is that the volume of its reservoir also increased following each moult, implying that more secretion can be stored and consequently the delivery also become more efficient. It is however in the 6th and adult instars with comparatively large reservoir and high volume of secretion that have the ability to discharge their secretion in the form of a spray. The energy requirement for all these are compensated for by the increasing number of tracheal endings attached to the gland in these instars (Idowu, 1996).

Table 1: Mean dimensions (±Standard error) in mm of repellent gland of *Zonocerus variegatus* (n = 5)

Instar	Length	Width	Volume (mm^3)	Width of orifice	Mean number of tracheal endings
1st	0.23±0.02	0.55±0.12	6		2±0.2
2nd	0.60±0.08	0.76±0.11	9		2±0.2
3rd	1.03±0.12	1.60±0.16	36	0.32	4±0.3
4th	1.54±0.11	2.27±0.12	62	0.48	5±0.6
5th	2.20±0.21	2.38±0.08	93	0.64	6±0.5
6th	3.01±0.09	2.85±0.11	156	0.80	12±1.6
Adult	5.02±0.13	3.80±0.22	225	1.12	25±1.9

Source: Idowu 1995

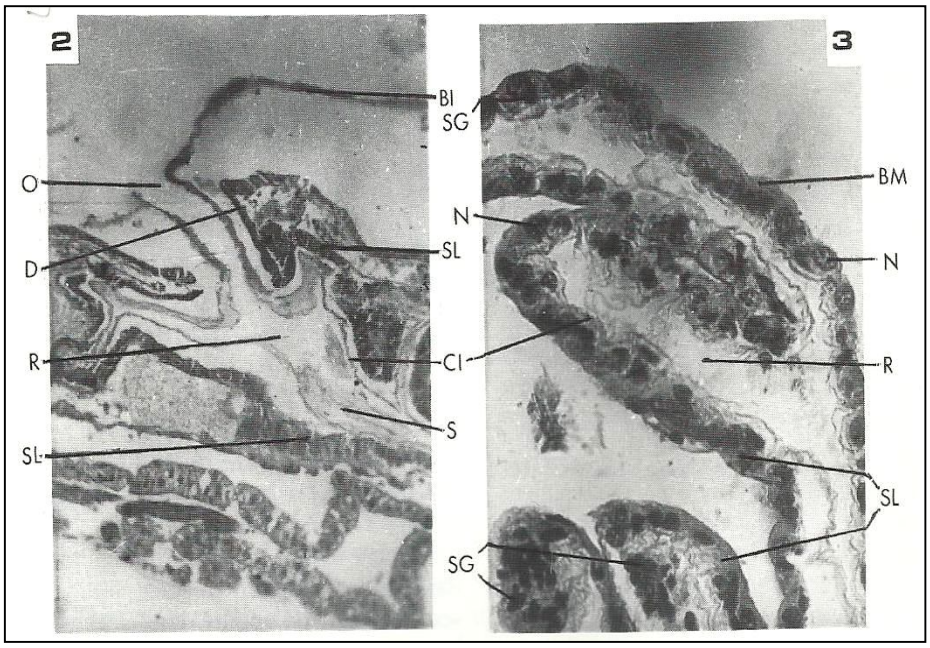


Plate 1a: Sections through the repellent gland of Zonocerus variegatus (40 x). (2) Longitudinal section of a 6th instar (Note the continuation of the gland wall and the cuticular intima with body wall and the cuticle of the exoskeleton); (3) Transverse section of a removed gland of an adult showing the secretory epithelium and the internal reservoir (lumen).
BI: body integument; BM: basement membrane; CI: cuticular intima; D: duct; O: gland orifice; N: nucleus; R: reservoir/lumen; S: seretion; SG: secretory granules; SL: secretory layer
Source: Idowu 1995

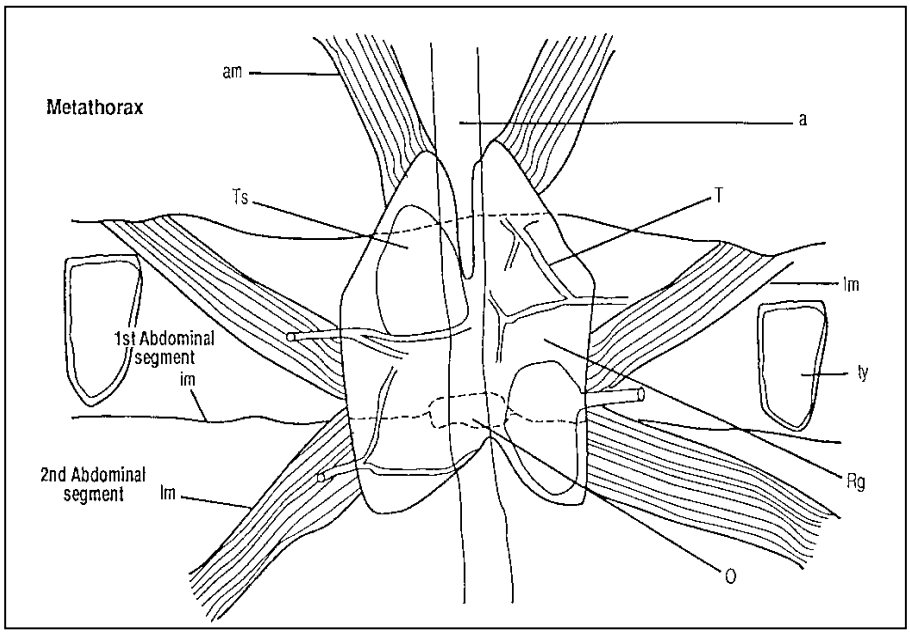


Figure 3: Location and morphology of the gland in adult Zonocerus variegatus in ventral view. a : aorta; am : anterior muscle; im : intersegmental membrane; lm : tracheal muscle; O : gland orifice; Rg : repellent gland; T : trachea; Ts : tracheal sec; ty : tympanum

Source: Idowu 1995

Table 2: Mean dimensions (±standard error) in μm of the secretory cells of Zonocerus variegatus gland in situ (n = 5)

Instars	Length	Width	Intima	Base-ment	Secretory cell nuclei per cell
3rd	19±2.0	16±1.0	9±0.6	6	-
4th	20±1.0	19±2.0	9±0.6	6	-
5th	25±1.1	23±0.7	9±0.6	6	-
6th	25±0.6	23±0.75	9±0.6	6	-
Adult	28±0.2	25±0.7	9±0.6	6	14±0.6

Source: Idowu 1995

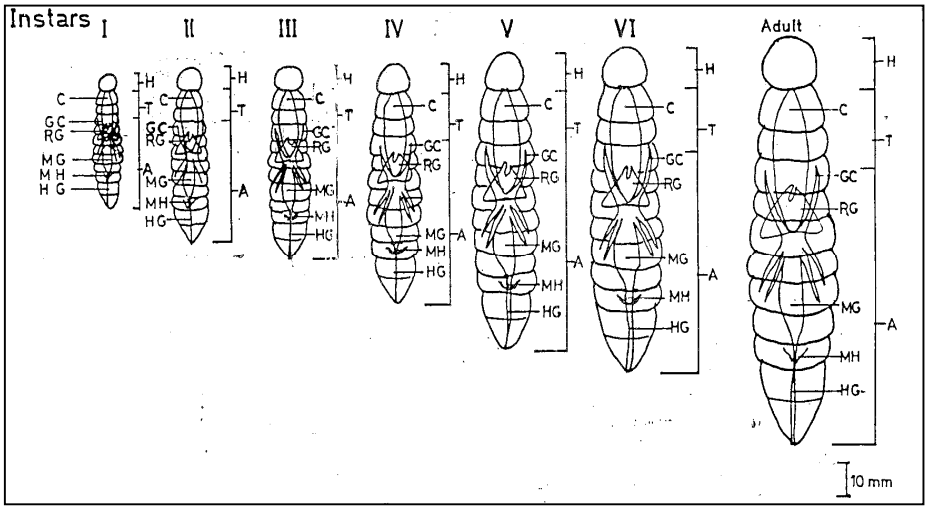


Figure 4: The position and the development of the repellent gland in the instars of Z. variegatus Source: Idowu 1996

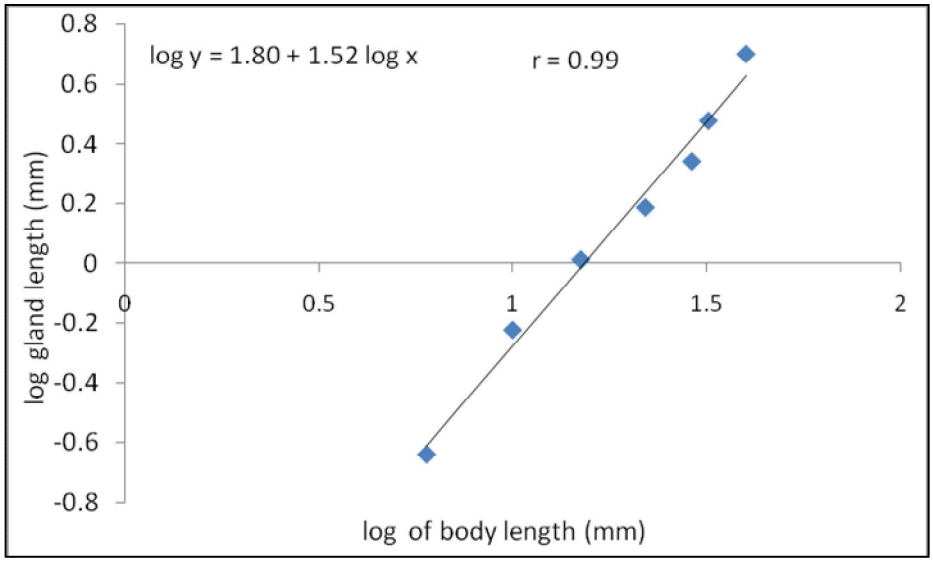


Figure 5: Relationship between body length and gland length in the instars (I – VII) of *Z. variegatus*
Source: Idowu 2000

4.1.2 **The Chemistry of the Repellent Gland and its Secretion**:

The repellent secretion is rich in protein, a common feature of defensive secretions (Graig and Stizel, 1986). Analysis of the chemical nature of the repellent secretion of the African grasshopper revealed that it contains alkaloids, glucose, proteins, free amino acids, trypsin-like proteinase, carbohydrases, lipase and the ions Ca^{2+}, Mg^{2+}, and K^{+} but not Na^{+} and $(PO_4)^{2-}$ (Table 3a). Alkaloids were present in the secretion of the

gland wall irrespective of the grasshopper's diet (Figure 6). (Alkaloids were present in the secretion whether or not the insects were fed on plants containing alkaloids). Moreover, the alkaloid was absent in the extract of the fat body and haemolymph of the same set of insects whose glands secretion were positive for the alkaloids. Interestingly, cyanide was absent in the secretion or the gland wall of *Zonocerus* raised exclusively on *M. esculenta* from the 1st instar. The secretion contains many amino acids which are similar whether the grasshoppers are fed on *Manihot esculenta* (cassava) or *Chromolaena odorata* (Akintola).

These results have shown that *Zonocerus variegatus* does not incorporate toxic compounds from food plants into its repellent secretions (Idowu and Modder, 1998). This is similar to the reports on the secretion of *Poekilocenus buforis* (Klug) (Fishelson, 1960). It thus appears that the chemical content of the repellent secretion are synthesized in situ and not sequestered from food, since they were present even when the grasshoppers were fed on plant that does not contain the active chemical compounds.

4.1.3 **Relationship between Zonocerus's Repellent gland and its food plants**

The volume of secretion obtained from adult *Zonocerus* repellent gland was influenced by the type of food plants eaten by

the grasshopper (Table 3b and c). Insects fed on leaves of cassava *manihot esculenta*, bitter leaves *Vernonia amygdalina* and a mixture of *M. Esculenta* and *Acalypha wilkesiana* gave a good volume of secretion. On the other hand *Chromolaena odorata, Aspilia africana* and *Citrus sinensis* did not favour secretion production (Idowu and Idowu, 2001). No signicant difference was recorded in the volume of secretion obtained from Z. variegatus from the two seasons irrespective of the food plant. Similarly, food plants gave no significant difference on the volume secretion between the two seasons.

The production of secretion by the repellent gland of *Zonocerus* is an important factor in the survival of the grasshopper from invertebrate and vertebrate predators (Idowu, 1997). The rate of recovery after a discharge is a key factor in the efficacy of the secretion as a defensive weapon. Thus, it is of a great adaptive significance for the grasshopper to feed on plants such as *M. esculenta* that will aid the refilling of its reservoir not long after a discharge (Idowu, 2001). This shows why Zonocerus will always be a major pest on the staple food of West Africa, cassava.

Zonocerus variegatus on cassava plant

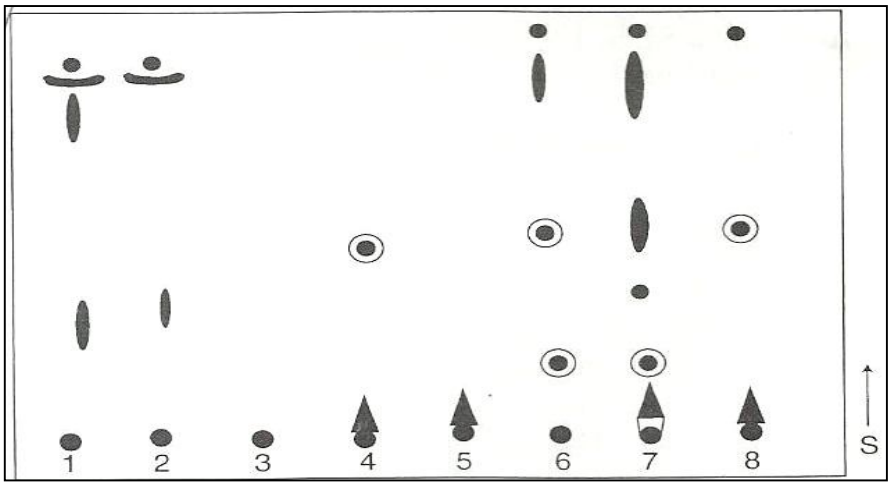


Figure 6: Diagram of the profile of the thin layer chromatography of the alkaloid content of Z. variegatus tissues and plant leaves extracts. Solvent mixture: Benzene: Ethyl acetate (3:1). S-source, - Direction of solvent flow. 1, chloroform extract of cassava leaves; 2, hexane extract of cassava leaves; 3, chloroform extract of fat body; 4, chloroform extract of repellent gland; 5, chloroform extract of haemolymph; 6, chloroform extract of C. Odorata; 7, hexane extract of C.odorata; 8, hexane extract of the repellent gland. Source: Idowu and Modder 1998

Table 3a: Concentrations of inorganic ions and amino acid identified in the repellent gland wall and secretion of adult *Zonocerus variegatus*

	Concentration (meq/l)				
	Ca^{2+}	Mg^{2+}	K^{+}	Na^{2+}	CN^{-}
Gland wall	4.5	1.65	7.53	0.0	0.0
Secretion	13.0	6.6	14.0	0.0	0.0
R_f	Probable amino acid				
0.084	Lysine				
0.10	Cysteine				
0.15	Cysteine/arginine				
0.24	Histidine				
0.28	Glutamic acid/glutamine				
0.32	α – Aminobutyric/cysteic acid				
0.41	Alycine				
0.42	Hydroxyproline/methionine sulphate				
0.50	Serine				
0.58	Proline				
0.65	Isoleucine/Methionine				
0.66	Leucine				
0.73	Tryptophan				

Source: Idowu and Modder 1998

4.1.4. **Mode of action of the Repellent Gland**

The repellent gland of *Zonocerus* stores secretion in its lumen (reservoir) and discharge of the secretion following any disturbance is a function of the size and volume of the gland lumen (Idowu, 1996) and can reach a distance of 42cm (Idowu,2000). The secretion which is ejected in the form of a jet-like spray is colourless to whitish, volatile, soluble in water, rich in chemical constituents (Idowu and Modder, 1998).

When approached or molested, the later instars of *Zonocerus variegatus* eject/expel through the gland orifice in between 1st and 2nd abdominal segments, an odorous milky secretion. The secretion has a penetrating and disagreeable odour (Idowu, 1997) which can even be perceived by human beings from a distance of several centimetres. The penetrating and unpleasant odour of the secretion caused the grasshopper to be avoided by vertebrate and invertebrate predators (Idowu, 1997). However, the praying mantids *Sphromantis lineola* was observed to feed very well on all the stages of the grasshopper without any after effect (Table 4a). The praying mantids may offer a way into the management of the variegated grasshopper as a pest.

In one of my studies, I observed that the ingestion of the grasshopper did not cause the death of the animals used for the experiment (Table 4b). However, the discharge of the re-

pellent secretion by *Z. variegatus* following disturbances and subsequent withdraw of the predatory animals showed that the repellent gland and its secretion are merely for repulsive protection. However, the body odour that is associated with *Z.variegatus* is not related to the odour of the food plants consumed by the grasshopper but identical to that of the secretion of the abdominal defensive gland (Idowu and Modder, 1996). This makes the insect repulsive to animals (man inclusive) and thus, the grasshopper is seen as a non-edible prey by other animals. A repellent secretion is one of the predominant defensive strategies of arthropods and their body odour which comes from the secretion is known to be an effective means by which potential predators recognise the inedibility of their prey (Pasteels *et al*., 1983).

Z. variegatus is aposemetically coloured (Chapman *et al*., 1986) and studies have also revealed that arthropods use their secondary defence to reinforce their primary defence (Whitman *et al*., 1990). Thus, the grasshopper in this case makes use of its repellent secretion (secondary defense) to reinforce its aposematic colouration (primary defense). Although, the secretion of *Z. variegatus* is non-lethal, it induced contraction in rat (*Rattus rattus*) stomach smooth muscle preparations and guinea pig (*Cavia porcellus*) ileum (Table 5) and also induced oedema formation in the rat hind paw (Table 6) (Idowu and Idowu, 1999).

The nymphs of Z. variegatus are commonly found in dense aggregations. The site of the aggregated insects creates fear in predatory animals and serves as a form of defence for the lower instars (1st, 2nd and 3rd) before the arrival of the repellent gland in the 4th instar larva. Ademolu *et al* (2010) has postulated that the high concentration of Ca^{2+} and Mg^{2+} in the early instars of Zonocerus block nerve conduction which might be responsible for the non-dispersion or gregarious habit of the lower instars.

Table 3b: Mean daily secretion (µl) obtained from wet season ***Z.variegatus*** **adult, fed on different food plants (+ S.E)**

	Days after emptying gland												
Host species	1	2	3	4	5	6	7	8	9	10	11	12	Overall Mortality
M. esculenta	No secretion	1.6ab +0.9	3.6a +0.8	5.2ab +0.6	6.3a +1.6	7.8a +2.2	14.6a +3.5	15.4a +1.5	16.6a +1.4	17.4a +1.6	16.2a +0.4	17.2a +1.4	0
V. amygdalina	No secretion	0.1b +0.1	2.4a +1.3	6.0a +1.0	6.1ab +1.2	8.4a +2.0	10.2b +1.9	13.3a +0.9	15.0a +0.2	15.6ab +0.2	15.6a +0.3	15.3a +1.0	0
M. esculenta + A. wilkwsiana	No secretion	1.4a +0.7	3.9a +2.1	4.9abc +0.8	5.1abc +0.5	5.8ab +0.4	9.0ab +0.9	11.7bc +1.0	13.6b +0.6	15.4ab +1.0	15.0a +1.91	14.6ab +2.4	0
A. wilkwsiana	No secretion	1.0ab +0.7	4.0a +0.1	6.3a +1.2	7.7a +2.1	7.5a +0.5	9.4b +0.2	10.7bc +1.4	13.2b +1.1	13.2bc +1.1	13.7ab +0.9	11.4b +1.6	0
J. abysinicca	No secretion	2.4a +0.7	3.6a +0.9	4.0abcd +0.6	6.6a +1.7	6.7ab +1.1	7.5bc +0.5	8.8c +0.1	10.8c +0.6	12.1c +1.2	12.1b +0.7	11.8b +1.3	24%
C. odorata	No secretion	0.2b +0.2	1.4a +0.7	2.3cd +0.5	4.2abc +0.3	6.8ab +1.1	5.5bc +1.3	3.7d +0.7	3.6d +0.7	3.5d +0.6	No secretion	No secretion	48%
A. Africana	No secretion	1.8ab +0.4	3.4a +1.3	3.7abcd +1.3	2.4c +1.5	4.6abc 0.4	3.6cd +0.5	3.5d +0.5	3.5d +0.4	3.1d +0.8	No secretion	No secretion	48%
E. guinensis	No secretion	0.5b +0.3	2.6a +1.0	2.7bcd +0.9	2.5bc +0.3	1.1c +0.6	0.4d +0.4	1.5d +0.4	1.8d +0.4	2.0d +0.2	No secretion	No secretion	53%
C. sinensis	No secretion	2.7a +0.5	2.3a +0.4	1.5d +0.4	2.0c +0.6	3.1bc +0.5	3.2cd +0.2	2.2d +0.4	2.2d +0.5	1.7d +0.4	No secretion	No secretion	56%
Starved	No secretion	0.8ab +0.6	2.4a +1.1	2.9cd 1.1	2.1c +1.0	2.5bc +1.2	No secretion	No secretion	No secretion	No secretion	No secretion	No secretion	68%

*Means followed by the same letter in a day are not significantly different by DMRT at 5% level
Source: Idowu and Idowu 2001

Table 3c: Mean secretion (µl) obtained from dry season, Z.variegatus adult, fed on different food plants (+ S.E)

	Days after emptying gland											
Host species	1	2	3	4	5	6	7	8	9	10	11	12
M. esculenta	No secretion	2.4a ±0.4	4.2a ±0.7	4.1a ±1.0	4.2a ±0.6	6.1b ±0.7	10.8a ±1.2	15.0a ±3.3	15.4a ±0.5	17.3a	16.8a ±0.8	16.6a
M. esculenta + A. wilkwsiana	No secretion	2.7a ±1.5	4.4a ±1.0	6.2a ±0.9	6.7a ±0.9	9.4a ±0.6	12.9a ±1.7	13.3a 1.4	13.9ab ±1.5	13.4 ±2.9	13.3a ±1.5	13.1a ±2.2
A. wilkwsiana	No secretion	1.2a	3.5a ±2.2	3.9a ±0.6	4.9a ±0.6	5.5a ±0.5	9.3a ±0.2	9.5a ±0.5	10.7b ±0.5	12.9a ±2.8	12.8a ±2.2	12.7a ±1.1
Starved	No secretion	0.26b ±0.46	2.4a ±2.3	2.9a ±2.6	2.1b ±1.9	2.9c ±2.7	No secretion	No secretion	No secretion	No secretion	No secretion	No secretion

*Means followed by the same letter in a day are not significantly different by DMRT at 5% level

Table 4a: Feeding of the praying mantids (*Sphromantis lineola*) on *Zonocerus variegatus* in cages a different densities

Prey instar	No. of Z. variegatus	No. of preys consumed by one mantid in 2hr		
		Replicates		
2nd	10	5	4	6
	20	4	5	7
	30	5	4	6
4th	10	5	5	4
	20	4	5	6
	30	5	6	4
6th	10	3	3	2
	20	2	3	4
	30	4	3	2
Adult	10	2	3	2
	20	3	2	2
	30	3	3	2

Source: Idowu 1997

Table 4b: Feeding of lizards (Agama agama) on *Zonocerus variegatus*

Z. variegatus instar	Replicates	No. of *Z. variegatus* consumed by one lizard in 2 hrs							
		Day 1		Day 3		Day 7		Day 14	
1st	1	8		6		7		5	
	2	6	22*	7	20*	3	18*	5	16*
	3	8		7		8		6	
2nd	1	6		8		5		4	
	2	4	17*	6	16*	2	12*	1	10*
	3	7		5		5		5	
3rd	1	4		5		5		4	
	2	5	16*	6	16*	2	12*	1	10*
	3	6		5		5		5	
4th	1	5		6		4		4	
	2	6	14*	4	14*	5	13*	4	14*
	3	3		4		4		6	
5th	1	2(1)		0		0		0	
	2	2(2)	5*	0		0		0	
	3	1(2)		0		0		0	
6th	1	3(3)		0		0		0	
	2	1(1)	6*	0		0		0	
	3	2(2)		0		0		0	
Adult	1	2(2)		0		0		0	
	2	2(2)	4*	0		0		0	
	3	0		0		0		0	

Number of Z. variegatus per cage/instar was 10. Figures in brackets indicate number of *Z. variegatus* regurgitated by the lizards. Figures with asteriks represent the total number of *Z. variegatus* consumed. Source: Idowu 1997

Table 5: Smooth muscle contractions induced by the repellent secretion of *Zonocerus variegatus* compared to that by acetylcholine

Ash concentration (M)	Size of contractions	Ach obtained (mm)	Dilution factor of secretion	Secretion (s) Contraction obtained (mm)	
	GPI	RS		GPI	RS
10^{-8}	23.3±1.73	23±2	0.1	10±2.1 (14%)	6±0.45 (10.2%)
2×10^{-8}	35.7±0.89	23.3±3.6	0.2	15±1.96 (21%)	12±1.8 (20.4%)
4×10^{-8}	50.3±3.2	33.7±1.5	0.4	30±2.3 (42%)	15±0.31 (25.4%)
8×10^{-8}	71.7±1.65 (100%)	59±2.4 (100%)	0.8	40±1.0 (56%)	30±0.69 (50.8%)

(n = 5)
Percentages ion brackets are comparing with maximal contraction obtained (Ach concentration of 8 x 10-8)
S = Repellent secretion of adult *Z.variegatus*
GPI = Guinea pig ileum
RS = Rat stomach
Source: Idowu and Idowu1999

Table 6: Oedema in the hind paw of wister rats, *Spraque dawley* induced by carragaenin and the repellent secretion of *Zonocerus variegatus*

Time (hr)	Mean diameter (mm) of oedema (±S.E)				Differences in mean diameter (mm)				% increase in diameter over initial diameter			
	S	C	C+S	D	S	C	C+S	D	S	C	C+S	D
0	26.0±4.4	26.8±0.95	25.8±2.4	26.0±2.08	-	-	-	-	-	-	-	-
3	34.4±2.45	35.5±3.94	39.1±2.08	27.0±2.65	7.5±1.94	8.7±2.99	13.3±0.22	1±0.57	28	32.5	52	3.9
6	36.1±3.39	38.8±3.98	39.1±2.89	26.7±2.89	9.2±1.00	11.5±3.03	13.3±0.59	0.7±0.8	34	43	52	2.7
12	31.6±1.51	34.5±5.67	36±3.51	26.0±3.61	4.7±2.88	7.2±4.72	10.2±1.21	0	17	29	39.5	-
24	28.4±2.28	28.6±4.09	34.3±2.08	26.0±3.61	1.5±2.12	1.8±3.14	8.5±0.22	0	5.6	6.7	32.9	

(N = 6)
S = 0.1 mm3 of the repellent secretion of adult *Z. variegatus*
C - 0.1 mm3 of carragaenin suspension (1 w/v in 0.9 saline solution)
C+S = 0.05 mm3 of carragaenin + 0.05 mm3 of the repellent secretion
D = 0.1 mm of distilled water
Source: Idowu and idowu 1999

4.2. 1 Relationship between *Zonocerus*, its microbial flora and food plants

Zonocerus variegatus is a polyphagous grasshopper (Chapman *et al*., 1986; Kekeunou *et al*., 2006), which appears to require a mixed diet for proper development (Idowu and Sonde, 2004) and production of its repellent secretion (Idowu and Idowu, 2001). Some of its food plants contain secondary compounds, such as cellulose and cyanogenic glucosides and their digestion is not easy for most animals since they lack the capacity to secrete enzymes that can hydrolyze these compounds. It therefore suggests that like most other animals, *Z. variegatus* will require the assistance of extracellular enzymes to process these secondary compounds in its food plants. Studies in cockroaches, termites and locusts have shown that the digestion of dietary cellulose was mediated by micro-organisms – denatured enzymes (Ohkuma, 2003; Delalibera *et al*., 2005). Together with late Dr(Mrs) Yinka Edema, we discovered that the alimentary canal of *Zonocerus* (fore-, mid- and hind gut) harboured a variety of micro-organisms, mainly bacteria, yeast and moulds (Tables 7) and the microbial load was highest in adult, followed by 6th, 4th and 3rd instars in that order (Idowu and Edema, 2002) .

The types of microbes in the gut regions of these instars are similar but significantly different in terms of total microbial load ($P \leq 0.05$). Result of the microbial counts generally did not show any significant differences among the adult and the

6th instars on one hand and the 3rd and 4th instars on the other hand ($P > 0.05$). These differences could be due to differences in diets among the instars. The early instars, 1st – 4th are known to prefer *Chromolaena odorata* while the later instars, 5th to adult feed and grow very well on *Manihot esculenta*. Idowu and Edema (2002) concluded that the types and numbers of microorganisms observed in their study are a reflection of the type and amount of food ingested by the different instars which is also a reflection of the capacity of their gut regions. Idowu *et al*. (2009) provided insight into the roles of microbes observed in the gut of the African pest grasshopper. This study showed that microorganisms found in the gut of *Z. variegatus have* capacity of synthesizing enzymes that assist the insects in degrading chemical constituents present in its diet (Tables 8 and 9). Studies on cockroaches, termites and locusts have also shown that the digestion of dietary cellulose was mediated by micro-organisms derived enzymes (Ohkuma, 2003). Idowu *et al*. (2009) also observed that most of the moulds isolated in the study were not able to liberate enzymes capable of digesting secondary chemical constituents; they may assist the orthopteran insects in other ways. There are reports that inhabiting symbionts play physiological roles such as the provision of essential nutrients for the host insects (Baumann *et al*., 2000; Akiman *et al*., 2002).

There are divergent views as to the origin of the microbes in

the guts of the arthropods. While some scientists believe that they are endogenous vertically transmitted to the next generation, others argue that they are exogenous, ingested along with food into the gut of the animals (Hunt and Charnley, 1981). The results of our studies (Idowu *et al*., 2003, 2009) are in agreement with exogeneous theory that the composition of the microbial flora in the gut of *Zonocerus variegatus* reflects its environment, indicating that the microbes are ingested by the insect along with its food. Closely related locust species *Schistocera gregaria* also derives its relatively simple microflora from ingested food plants, which thereafter multiply within its gut (Dillon *et al*., 2000). In support of the exogenous origin of microbes in the gut of *Z. variegatus*, Ademolu and Idowu (2011) reported that the gut of newly hatched 1st instars of *Zonocerus* was sterile of microbes, meaning that no micro-organisms were vertically transmitted.

Our studies have provided insight into the physiological mechanisms by which *Z. variegatus* is able to live successfully on food plants that are rich in potentially toxic secondary compounds. These compounds are processed by enzymes derived from micro-organisms ingested with the insect's diet. Evidently, gut microbiota of *Z. variegatus* constitute critical metabolic resources for the grasshopper. The transformation of plant secondary compounds by microbial-mediated enzymes has led to the grasshopper's successful adaptation to

diverse plant species, particularly cassava, leading to the insect's current status as a major agricultural pest in Nigeria and surrounding regions.

Zonocerus variegatus on Cassava plant

Table 7: Distribution of isolated micro flora in the gut of instars of *Zonocerus variegatus*

	Adult	6th instar	4th instar	3rd instar	Adult	6th instar	4th instar	3rd instar	Adult	6th instar	4th instar	3rd instar
Gut Regions	**Yeast**				**Moulds**				**Bacteria**			
Foregut	YI	YI, YII	YI, YII	YI	MI	-	-	MI	BI, BII, BIV	BI, BIV	BII, BIII	BII, BIII
Foregut content	YI, YII, YIII	YI, YIV	YI, YII	YI	-	MII	MII	MI	BV, BVII, BVIII	BII, BIII	BII	BII, BIV
Midgut	YII	YII, YIII	YI, YIV	YII	MI	-	MIII	MI	BII, BIV, BV	BII, BIX	BIV, BVI	BIV, BIX
Midgut content	YI, YII	YI, YII	YI, YIII	YII	-	MII	MIV	MIII	BI, BII, BIII	BII, BIII	BII, BIV	BII, BIV
Hindgut	YI, YII	YI, YII	YI, YIII	YII	-	MIII	-	MIII	BVI	BII, BIII, BVI	BIV, BVI	BII, BIV
Hindgut content	YI	YI, YIV	YI, YIII	YI, YII	-	MIII	MIV	MIII	BV, BVI	BVI, BIX	BII, BIV	BII, BIV
Gastric caeca	YI, YII	YI, YII, YIII	YIV	YI	-	-	MII	MII	BV, BVI	BII, BIII	BII, BV	BII

YI – *Candida* sp., YII – *Saccharomyces cerevisae*, YIII – *Saccharomyces sp.* and YIV – *Pichia sp.*
MI – *Aspergillus*, MII – *Penicillum sp.*, MIII – *Fusarium sp.* And MIV - *Rhizopus*
BI – *Proteus sp.*, BII – *Alcaliges sp.*, BIII – *Streptococcus sp.*, BIV – *Escherichia coli*, BV – *Lactobacillus sp.*, BVI – *Enterobacter sp.*, BVII – *Pseudomonas*, BVIII – *Staphylococcus sp.* and BIX – *Serratia sp.*
Source: Idowu and Edema 2002

Table 8: Enzymatic activity profile of bacterial isolates from the gut regions of *Zonocerus variegatus*

Stage	Isolate	Organism identified	Lipase	Amylase	Esterase	Protease	Linamarase	Cellulase
Adult	B_1	*Acinetobacter sp.*	-	-	+	+	+	+
	B_2	*Bacillus sp.*	-	+	+	+	+	+
	B_3	*Acaligenes sp.*	-	-	-	+	+	+
	B_4	*Microbacterium*	-	+	+	-	+	-
	B_5	*Klesbiesella sp.*	-	-	+	-	+	-
6th instar	B_6	*Proteus mirabilis*	-	-	-	-	-	+
	B_7	*Staphylococcus aureus*	-	-	-	+	-	-
	B_8	*Clostridium sp.*	-	-	-	+	-	+
5th instar	B_9	*Eschrichia coli*	-	-	-	-	+	-
	B_{10}	*Pseudomonas*	-	-	-	-	-	+
4th instar	B_1	*Acinetobacter*	-	-	+	+	+	+
	B_{11}	*Enterobacter sp*	-	-	-	-	-	-
	B_{12}	*Corynebacterium sp.*	-	-	-	-	-	-
	B_{13}	*Streptococcus sp.*	-	-	-	-	-	-
3rd instar	B_{15}	*E. coli*	-	-	-	-	+	+
	B_1	*Acinetobacter sp.*	-	-	+	+	+	+
	B_2	*Bacillus sp.*	-	-	+	+	+	-
	B_{13}	*Streptococcus sp.*	-	-	-	-	-	-
	B_{14}	*Serratia sp.*	-	-	-	-	-	-

– , negative, i.e. organism isolated at that stage did not produce the enzyme; + , positive, i.e. organism isolated at that stage produced the enzyme.
Source: Idowu *et al* 2009

Table 9: Enzymatic activity profile of yeast (Y) and mould (M) isolates from *Zonocerus variegatus*

Isolate code	Organism identified	Lipase	Amylase	Esterase	Protease	Linamarase	Cellulase
Y_1	*Candida sp.*	-	+	-	+	+	+
Y_2	*Saccharomyces sp.*	-	+	+	-	-	-
Y_3	*Geotrichium sp.*	-	-	-	-	-	-
Y_4	*Pichia sp.*	-	+	-	+	-	-
M_1	*Aspergillus niger*	+	-	-	-	-	-
M_2	*Aspergillus ochraceus*	-	-	-	-	-	-
M_3	*Trichoderma*	-	-	-	-	-	-
M_4	*Penicillium sp.*	-	-	-	-	-	-
M_5	*Rhizopus sp.*	-	-	-	-	-	-

– , did not produce the enzyme; + , produced the enzyme.
Source: Idowu *et al*2009

4. 3. Zonocerus and Entomophagy

Lev 11:22: *Even these of them ye may eat; the locust after his kind, and the bald locust after his kind, and the beetle after his kind, and the grasshopper after his kind*.

Z. variegatus is an item of diet in Ikare, Owo and Oka, all in Ondo state (Table 10a and 10b) (Idowu and Moder, 1996). Page and Richards (1977) had earlier reported that the insect is an item of diet in some areas surveyed in the eastern part of Nigeria. The insect is eaten either after boiling, frying or roasting, but the majority prefer eating it in the fried form. Although, the respondents in these towns sees feeding on grasshoppers as control strategy, studies have shown that both raw and processed grasshopper respectively are higher and compare favourably with some conventional and unconventional protein sources such as beef (22.2%), pork (21.6%), elephant (30.9%) and African giant snail (18.28%) (Pearson, 1982; Ajayi and Tewe,1985). Sequel to the report of Idowu and Modder (1996), we designed in the laboratory, five different processing methods to prepare *Z. variegatus* for human consumption as shown in Figure 7 (Idowu *et al*, 2004). *Zonocerus* processed by methods 1 and 2 were significantly different from those obtained from methods 3,4and 5 in all the attributes tested (Table 11 and 12). Although, samples 1 and 2 were similar in aroma and appearance, they differed in taste and texture.Improved products with better appearance and texture

found in samples 1 and 2 may be due to boiling for 4 minutes that distinguish both methods and which must have helped to detoxify and remove the unpleasant taste and odours associated with the live insect (Idowu, 1994). The conclusion was that boiling, removal of wings, decapitation, frying or roasting are the necessary processing operations needed to make the grasshopper acceptable for human consumption. The processed grasshopper was richer in protein, ether extract and some mineral elements when compared to the raw samples (Table 13). The work of Ademolu *et al*. (2010) confirmed that the adult instars of *Zonocerus* as well as other instars have high crude protein (Table 14). Infact there was no significant difference between the protein content of adult and 1st instars. Ademolu *et al* (2010) also showed that the body of *Zonocerus* instars were very rich in Vitamins A, B_2 and C and the values of the vitamins increased in the insect as it moulted from one stage of development till it reached the highest vitamin content in the adult *Zonocerus* (Table 15). The ash of processed *Z. variegatus* was found to be rich in potassium, magnesium, copper and sodium (Idowu *et al* 2004) and recently Ademolu *et al* (2010) provided information that the ash content of all instars of *Zonocerus* are rich in mineral elements with additional data that the lower instars of the African pest grasshopper are richer in mineral content than the later instars and therefore the lower instars are able to contribute more mineral like Zn^{2+}, Mg^{2+}, Fe^{2+}, and Ca^{2+} to animal and human diets than

higher instars (Table 16). These findings have shown that Z. variegatus is a nutritious insect that can be included in the diet of animals as earlier reported by Okoye *et al* 2007. I feel greatly that the insect therefore could serve as a complementary protein source for human consumption. The crude fibre of the insect is about 1.2% and it could be useful in regulatory coloric function in man (Cadden, 1988).

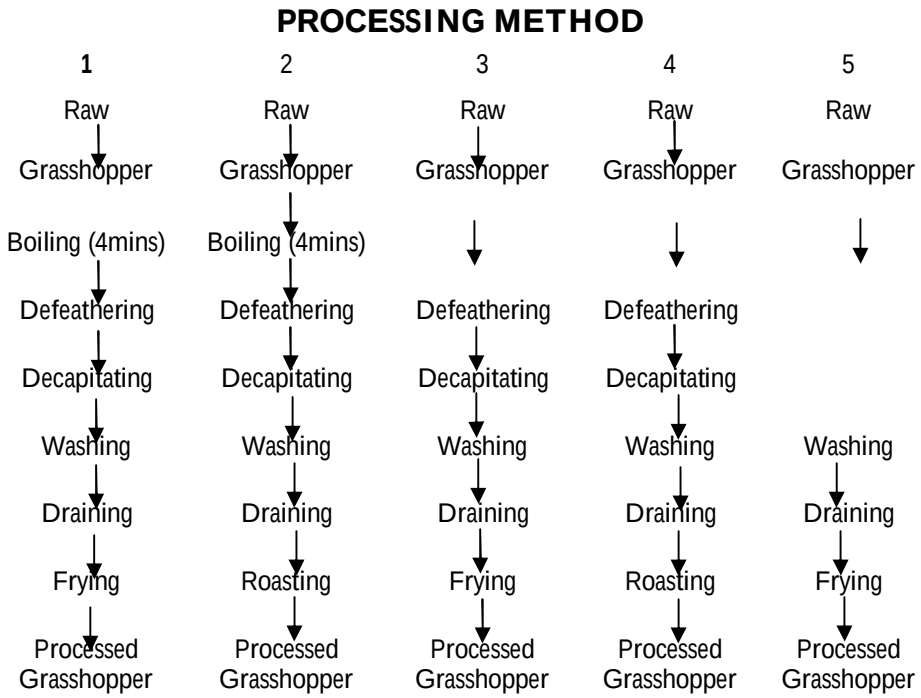


Figure 7: Five different methods for processing Z. variegatus
Source: Idowu *et al* 2007

Table 10a: Percentage of respondents on the mode of eating and their opinion on taste of Z. variegatus N = 70 (100%)

	Percentages of respondents stating that Z. variegatus is:							
Town	Raw	Best boiled	Eaten fried	Roasted	Best eaten Immediately	After storage of 1–30 days	Palatable	Unpalatable
Ikare	0	2.8	61.1	36.1	68.6	31.4	94.3	5.7
Oka	0	10.3	82.8	6.9	64.7	35.3	96.1	3.9
Owo	0	2.9	50	47.1	47.1	52.9	87.5	12.5

Source: Idowu and Modder. 1996

Table 10b: Z. variegatus as an item of diet in three towns in Ondo state: N = 70 (100%)

	Percentage of respondents on Z. variegatus as an item of diet:			
Town	Eaters	Non eaters	Eaters still consuming insects	Eaters no longer consuming insects
Ikare	68.4	31.6	47.2	52.8
Oka	83.8	16.2	39.2	60.8
Owo	77.5	22.5	52.9	47.1

Source: Idowu and Modder. 1996

Table 11: Mean scores* for sensory evaluation of processed Zonocerus variegatus (Difference Test)

Product	Aroma	Taste	Texture	Appearance
1	1.5±0.65a	1.3±0.47a	1.3±0.47a	1.4±0.47a
2	1.7±0.62a	1.7±0.47a	1.8±0.80b	1.7±0.47a
3	3.1±0.85b	3.5±0.77b	3.3±0.50c	3.3±0.43b
4	4.1±0.60c	3.9±0.64c	3.9±0.76d	3.9±0.64c
5	4.4±0.64c	4.9±0.64d	4.6±0.76e	4.8±0.28d

*mean scores with same letters in a column are not significantly different (P > 0.05) using the Duncan Multiple Range Test (DMRT)
Source: Idowu *et al* 2007

Table 12: Mean scores* for sensory evaluation of processed Zonocerus variegatus (Preference Test)

Product	Aroma	Taste	Texture	Appearance	Overall Acceptability
1	7.0±1.68a	7.0±1.29a	6.9±0.95a	7.5±1.12a	7.7±0.94a
2	7.0±1.78a	6.8±1.48a	6.7±1.31a	7.0±1.08a	7.2±1.21a
3	5.5±1.12a	4.3±1.93b	4.5±1.38b	4.4±1.04b	5.0±1.73b
4	4.3±1.89b	4.5±1.61b	4.3±1.83b	3.6±1.85b	4.3±2.2b
5	4.1±2.23b	3.5±1.66b	3.4±1.61b	3.2±1.95b	3.8±1.68b

*Mean scores with same letters in a column are not significantly different (P > 0.05) using the Duncan Multiple Range Test (DMRT
Source: Idowu *et al* 2007

Table 13: Nutrient composition and mineral content of raw and processed *Zonocerus variegatus* (n=10)

	Raw	**Processed**
Moisture (%)	64.28±0.08	10.67± 0.28
Crude Protein (%)	27.05±0.10	61.65±0.20
Ether Extract (%)	8.64±0.05	20.73±0.54
Ash (%)	0.49±0.11	1.25±0.40
Fibre (%)	0.19±0.02	1.45±0.02
Carbohydrate by Different	ND	4.25±0.70
(%)	82.0	150.0
Potassium (ppm)	6.0	33
Sodium (ppm)	3.7	9.1
Calcium (ppm)	3.4	75.6
Magnesium (ppm)	0.9	10.7
Iron (ppm)	ND	2.7
Manganese (ppm)	ND	70.3
Copper (ppm)	ND	0.03

ND Not determined
Source: Idowu *et al* 2007

Table 14: Proximate analysis of *Zonocerus variegatus* during post-embryonic development (%)

Stages	Moisture content	Crude fat	Crude protein	Crude fibre	Ash content	Carbohydrates
1st	74.19±0.00ab	4.30±0.2b	18.31±0.00ab	0.85±0.1c	1.93±0.02a	0.42±0.2b
2nd	74.52±0.01ab	4.77±0.00a	14.4±1.80b	0.92±0.00c	1.00±0.1cd	0.39±0.1b
3rd	77.14±1.0a	2.86±0.1c	16.81±0.00ab	1.45±0.05a	0.87±0.00d	0.87±0.02b
4th	71.64±0.06ab	0.71±0.02e	15.52±2.0b	0.89±0.01c	1.59±0.01ab	9.65±0.05a
5th	72.08±3.92ab	1.07±0.03d	14.61±2.0b	0.90±0.00c	1.57±0.01ab	9.77±0.1a
6th	71.71±0.2ab	0.91±0.00de	16.1±1.9ab	0.98±0.01c	1.49±0.2b	8.81±2.01a
Adult	65.92±0.5b	0.85±0.05de	21.38±0.02a	1.23±0.02b	1.40±0.2bc	10.02±0.02a

**Mean values (±S.E) in the column having the same superscript are not significantly difference (P > 0.05) (SNK).
Source: Ademolu *et al* 2010

Table 15: Vitamin content of *Zonocerus variegatus* during post-embryonic development (µg/100g) (dry weight)

Stages	Vitamin A	Vitamin B	Vitamin C
1st	111.79±1.0f	0.025±0.1	1.6±0.02f
2nd	293.22±2.0f	0.035±0.52	2.2±0.2ef
3rd	366.13±0.0e	0.05±0.01	2.8±0.2de
4th	4441.18±0.1d	0.055±0.05	3.2±1.0d
5th	576.93±0.0c	0.065±0.00	5.3±0.30c
6th	627.83±0.1b	0.075±0.05	9.5±0.50b
Adult	814.49±3.0a	0.095±0.00	11.7±0.20a

**Mean values (±S.E) in the column having the same superscript are not significantly difference (P > 0.05) (SNK).
Source: Ademolu *et al* 2010

Table 16: Mineral content of *Zonocerus variegatus* during post-embryonic development (mg/g) (dry weight)

Stages	Ca2+	Mg2+	Zn	Na+	K+	Fe	P	Na+/K+
1st	5.52±0.02b	0.96±0.03a	0.29±0.04a	13.50±0.00b	20.3±0.3ab	9.10±0.1a	45±5.0e	0.67±0.01a
2nd	4.95±0.05b	0.96±0.01a	0.32±0.02a	12.55±0.05c	24.2±0.2a	8.29±0.2b	90±2.0d	0.52±0.02abc
3rd	5.83±0.1b	0.34±0.02bc	0.15±0.00b	13.75±0.05a	23.0±2.0a	9.23±0.02a	115±2.0cd	0.60±0.1ab
4th	0.94±0.2c	0.34±0.02bc	0.15±0.00b	2.97±0.01e	8.66±0.1c	1.26±0.00e	122±1.0c	0.34±0.4c
5th	0.72±0.02c	0.39±0.01b	0.18±0.02d	3.05±0.05e	7.67±0.2c	1.19±0.02e	163±3.0b	0.40±0.00bc
6th	7.22±1.0a	0.31±0.01c	0.19±0.02c	6.94±0.04d	15.0±0.1b	7.71±0.00c	190±3.0b	0.46±0.02bc
Adult	1.82±0.02c	0.39±0.1b	0.17±0.02b	3.06±0.00e	7.61±0.00e	1.84±0.1d	218±1.0a	0.40±0.1bc

**Mean values (±S.E) in the column having the same superscript are not significantly difference (P > 0.05) (SNK).
Source: Ademolu *et al* 2010

However, Idowu *et al* (2007) reported that *Z. variegatus* like other arthropods could accumulate and magnify heavy metals in its body (Table 17) and that the nature of its sites of collection had a significant effect on the type and concentration of heavy metals found in the body of the grasshopper. There is therefore the need to closely monitor the concentration of metals in the body of *Z. variegatus* especially in the areas where the insect is an item of human diet.

On the other hand, our research work has also shown that all castes of *Macrotermes bellicosus* from locations either polluted or not, have great nutritive potential and have lower tendency to accumulate heavy metals (Table 18) (Idowu *et al*. 2014). Also, not only the winged termites are nutritionally important but all castes of the termite colony which includes the workers, soldiers and the reproductive (queen and king) irrespective of their environment (Table 18).

Insects are highly nutritious and healthy food source with high fat, protein, vitamins, fibre and mineral contents and are likely to play significant role in survival of mankind by 2050 when the world will host 9 billion people (FAO 2014). Although the majority of edible insects are gathered from forest habitats, innovation in mass-rearing systems has begun in many countries. Insects offer a significant opportunity to merge traditional knowledge and modern science in both developed and

developing countries. I was at the international conference on Edible insects held in Holland in 2014 and what I saw was amazing. The Chinese came into the conference with prepared and well packaged insect cuisine selling for €80-120 and I was amazed at the sales they made; none returned with them to their country. Right now the European Union is encouraging her citizens to go into the production of insects both for consumption and for other usages backed with a lot of grants.

Entomophagy, "insect-eating", is becoming a serious business in America and Europe as their government is putting so much into it by funding of researches, feeding trials and campaigns for the acceptance of the concept of entomophagy. This is one area that we have the natural endowment and our government can venture into it for intensive employment generation. Please pray with me that God will open the eyes of men in Nigerian Government to the opportunities available in this respect. We should think now of creating the enabling environment for mass production, processing, packaging and marketing of insects for consumption. We should not wait for its importation like organic farming.

Table 17: Heavy metal content (mg/100g) of *Z.variegatus*, host plants and soil from various locations within Abeokuta

Location	*Z. variegatus*				Host plant				Soil			
	Zn	Cu	Cr	Pb	Zn	Cu	Cr	Pb	Zn	Cu	Cr	Pb
Mechanics' village	0.207a	0.057b	0.130ab	0.166ab	0.043b	0.0078bc	0.064b	0.122b	0.020c	0.015b	0.186bc	0.328a
Sam-Ewang Estate	0.098b	0.075a	0.140a	0.102b	0.041b	0.0084b	0.072b	0.130b	0.109b	0.016b	0.132c	0.040c
Abeokuta-Ibadan Exp Rd.	0.123ab	0.062ab	0.116b	0.096b	0.025b	0.0116b	0.058bc	0.104b	0.055c	0.032a	0.362a	0.170b
UNAAB Petrol Station	0.162ab	0.081a	0.052c	0.068b	0.046b	0.0184a	0.120a	0.120b	0.155b	0.005c	0.244b	0.160b
Ita-Oshin industrial Estate	0.143ab	0.070a	0.102b	0.300a	0.310a	0.018a	0.062b	0.088b	0.357a	0.013b	0.142c	0.140b
UNAAB Farm	0.176b	0.083a	0.100b	0.10b	0.060b	0.008b	0.092a	0.317a	0.037c	0.005c	0.178bc	0.124b

Source: Idowu *et al*2007

Table 18: Minerals and heavy metal analysis of termite (mg/l)

	Refuse Dump			Industrial Area		Farm Area		
	Reproductives	Soldiers	Workers	Soldiers	Workers	Reproductives	Soldiers	Workers
Mg^{2+}	2.026±0.002^{a}	1.601±0.001^{c}	0.327±0.002^{d}	0.230±0.01^{f}	0.280±0.01^{e}	1.948±0.001^{b}	0.182±0.001^{g}	0.242±0.001^{f}
Cu^{2+}	0.020±0.01^{c}	0.017±0.002^{c}	0.047±0.002^{b}	0.076±0.001^{a}	0.070±0.01^{a}	0.030±0.01^{bc}	0.024±0.001^{c}	0.048±0.001^{b}
Cr^{2+}	0.145±0.002^{e}	Nil	0.223±0.003^{a}	0.196±0.002^{b}	0.181±0.001^{d}	0.178±0.001^{d}	0.185±0.001^{c}	0.226±0.001^{a}
Fe^{2+}	0.036±0.002^{h}	0.686±0.002^{f}	5.004±0.002^{a}	0.701±0.001^{e}	0.832±0.001^{d}	1.623±0.002^{c}	0.389±0.001^{g}	1.855±0.002^{b}
Pb^{2+}	Nil	Nil	0.076±0.002^{a}	Nil	0.012±0.001^{b}	Nil	Nil	0.08±0.01^{a}
Zn^{2+}	0.001±0.000^{c}	0.003±0.001^{c}	0.001±0.000^{c}	0.028±0.001^{b}	0.028±0.001^{b}	0.002±0.001^{c}	0.099±0.002^{a}	0.003±0.001^{c}

**Mean values (+S.E) in the same column having the same superscripts are not significantly different
(P > 0.05). Source: Idowu *et al* 2014

Table 19 : Proximate analysis (g/100g) of termite samples

	Refuse Dump			Industrial Area		Farm Area		
	Reproductives	Soldiers	Workers	Soldiers	Workers	Reproductives	Soldiers	Workers
Moisture Content	81.94±0.01^{a}	74.62±0.01^{e}	72.41±0.01^{f}	70.42±0.02^{h}	70.52±0.02^{g}	80.27±0.01^{b}	74.76±0.01^{d}	75.80±0.02^{c}
Dry Matter	18.06±0.01^{h}	25.38±0.01^{d}	27.59±0.01^{c}	29.58±0.01^{a}	29.48±0.01^{b}	19.73±0.01^{g}	25.24±0.01^{e}	24.20±0.02^{f}
Fat Content	1.62±0.01^{b}	1.48±0.01^{c}	1.60±0.01^{b}	1.68±0.01^{ab}	1.70±0.01^{ab}	1.78±0.01^{a}	1.46±0.01^{c}	1.41±0.01^{c}
Ash Content	1.02±0.01^{f}	1.98±0.01^{c}	2.15±0.02^{b}	2.27±0.02^{a}	2.27±0.02^{a}	1.09±0.01^{e}	1.97±0.01^{c}	1.87±0.01^{d}
Crude Fibre	0.53±0.01^{h}	0.88±0.01^{d}	0.94±0.01^{c}	1.02±0.02^{b}	1.04±0.02^{a}	0.61±0.01^{g}	0.86±0.01^{e}	0.81±0.01^{f}
Crude Protein	14.31±0.01^{h}	18.56±0.01^{d}	19.59±0.01^{c}	20.96±0.01^{a}	20.82±0.02^{b}	15.39±0.01^{g}	18.33±0.01^{e}	17.76±0.01^{f}
Carbohydrate Content	0.58±0.01^{g}	2.48±0.01^{d}	3.31±0.02^{b}	3.65±0.01^{a}	3.65±0.01^{a}	0.86±0.01^{f}	2.62±0.02^{c}	2.35±0.01^{e}

**Mean values (+S.E) in the same column having the same superscripts are not significantly different (P > 0.05). Source: Idowu *et al* 2014

4.4 SNAILS STUDIES

Land snails are the commonest mollusks in Nigeria and Africa, and they have long been considered of high nutritional and medical importance. Snail meat is rich in minerals and amino acids and also low in lipid, cholesterol and saturated fatty acid contents (Imevbore and Admosun, 1988). Ademolu *et al* (2004) reported that the flesh and haemolymph of the African giant land snail (*Archachatina marginata*) is rich in Ca^{2+}, Mg^{+}, Na^{+}, K^{+}, Zn^{+}, Fe^{+} and Cl^{-}.

The only comparative study on African land snails was that of Idowu and Akinnusi (2005), which was on the structure of the ovotestis of African land snail found in Abeokuta viz, *Archachatina marginata, Achatina achatina, A. folica, Helix pomatia and*

Limcolaria aurora. Of all the species examined only the ovotestis of *H. pomatia* could not be observed despite the fact that they are matured specimens. It is possible that the removal of *H.pomatia* from its aquatic environment probably halted the development of its ovotestis. Boyle and Yoshino (1999) in a related study observed that when water source was changed in *B. glabrata*, the functioning of the ovotestis was halted. The results of the study revealed that the positioning, shape and arrangement of the ovotestis was the same for all the four species. The ovotestis is embedded in the digestive gland at the anterior region of the coiled posterior end of the visceral mass. It is cream coloured and made up of sac-like lobes arranged on a single plane. It is also differentiated into an ovarian and a testicular region. The number and sizes of the lobes of an ovotestis differ significantly ($P \leq 0.05$) in all the snails. Each lobe is made of several follicles, the number of which varied in the four species. Interestingly, correlation analysis showed that live weight, shell length, width and circumference have no influence on the size of the ovotestis (Idowu and Akinnusi, 2005). The results of chromosomal examination of the species showed haploid chromosome numbers n=28 for *A.marginata*, n=22 for A. achatina, n-27 for A. fulica and n=14 for *L.aurora*. This observation agrees with the results of Fagbuaro *et al* (2002). No special sex chromosome was observed as earlier reported by White (1977).

In this part of the world, four major species of giant African

land snail (GALS) are popular: *Archachatina marginata, Achatina achatina, Achatina fulica* and *Limicolaria aurora*. Idowu *et al* (2008) did a comparative analysis of the four species and discovered that *A. marginata* had the highest protein content (Table 20). No wonder the high price of snails in the market. It supplies high protein content but low fat content, making it suitable for all and sundry without any side effect.

The impact of human activities such as deforestation, slash and burn, agricultural practices and indiscriminate snail hunting has reduced the population of these species in the wild (Ejidike, 2002). Also, many benefits derived from snails ranging from nutritional, medical and industrial had made their domestication a popular phenomenon. The major problem with its domestication is the actual number to stock in a particular unit area. Our study on the stocking density of *Archatina marginata* showed that for optimal utilization of both flesh and haemolymph, stocking should be done at 60 snails per m^2 (Ademolu *et al*., 2006). We observed a strong relationship between stocking density and the concentration of the haemolymph protein, glucose and lipids.

Snails consume and convert many household and farm wastes as well as many food plants into body nutrients. Due to seasonality of pawpaw leaves and other preferred plants, formulation of diet is now recommended for efficient management of Giant African Land Snails (GALS). Among other nitrogen sources used in diet formulation, we found out that poultry

dropping contributed more to the growth performance and nutritive value of *A. marginata* than other nitrogen sources (Table 21) (Ademolu *et al* 2006). The snails fed with poultry dropping recorded higher weight gain and protein content than those fed with plant materials.

Table 20: Proximate composition of the flesh of four common snails found in Abeokuta*

Snail Samples	Moisture Content	Fat Content (g/100)	Ash Content (g/100g)	Crude protein Content (g/10g)	Crude fibre Content (g/100g)	Carbohydrate Content (g/100)
A.marginata	72.39±3.1	3.68±5.8^{b}	1.45±0.1	16.08±1.7^{a}	3.12±0.8	3.28±1.1^{b}
A.achatina	77.81±0.5	2.26±0.8^{c}	1.77±0.4	13.16±0.7^{b}	3.01±0.1	1.99±0.2^{c}
A.fulica	79.58±0.6	1.61±1.22^{d}	1.89±0.5	10.24±0.6^{c}	3.24±0.3	3.44±0.1^{b}
L.aurora	76.00±0.9	4.8±1.0^{a}	2.78±5.7	7.67±5.7^{d}	4.21±0.1	4.54±0.1^{a}

*Mean values in each column with the different superscripts are significantly different ($p<0.05$)
Source: Idowu *et al* (2008)

Table 21: Growth performance of *A. marginata* fed different nitrogen based diets*

Parameters	Soybean based diet	Fishmeal based diet	Poultry dropping based diet	Urea based diet	Pawpaw leaves
Feed intake (g)	218.02±0.84^{c}	220.64±0.56^{c}	495.37±2.93^{b}	116.37±0.6^{d}	902.23±0.01^{a}
Weight gained (g)	10.55±0.5^{c}	9.37±0.4^{c}	14.02±0.6^{a}	5.97±0.1^{d}	11.97±0.4^{b}
Shell length gained (cm)	1.013±0.01^{b}	0.88±0.2^{c}	1.16±0.02^{a}	0.002±0.001^{d}	0.004±0.001^{d}
Shell circum-ference gained (cm)	1.28±0.01^{b}	0.81±0.02^{c}	1.84±0.02^{a}	1.03±0.003^{b}	1.50±0.1^{b}

*Mean values in each row with the same superscript are not significantly different (p>0.05).
Source: Ademolu *et al* (2007)

Aestivation is a state of rest with very low or reduced metabolic activities. It is an old behavior of snail during adverse condition. It was found that during aestivation, *A. marginata* has reduced muscular and digestive activities, as enzymes activities in both the femoral muscles and gut reduced significantly compared to when they are active.

The reproductive performance of GALS is species-specific. *A. marginata* lays 8-10 eggs (3.07g), *A. achatina,* 100-300 eggs (0.15g) while A *fulica* 6-8 eggs (0.43g) (Okon and Ibom, 2014). The reason for these variations may be genetic, physiological and morphological. Our assessment of the reproductive tracts of three common GALS revealed that size (morphology) of the reproductive tracts gave a better insight into the size of eggs produced as wider, bigger and longer tract will allow for better egg development (Ademolu *et al*, 2010). Idowu and Akinnusi (2005) similarly examined the structure of ovotestis of common GALS in Abeokuta, Ogun State. It was discovered that the number and size of the lobes of the ovotestis differed significantly in all the snails and the meiotic metaphase spreads of the ovotestis tissues revealed chromosome numbers 2n=56,2n=44,2n=54 and 2n=28 for *A.marginata, A.achatina, A.fulica and L.aurora* respectively (Table 22).

In other to expand the scope of snail culturing in South west Nigeria, the physiology of the so called "Igbin Osa" (Albino snails) was studied. Results revealed that Albino snails had

lower growth rate but, higher concentration of Na^{+} and PO_4^{2+} in the heamolymph than normal snails, which makes them more aggressive and better adaptable to the environment (Ademolu *et al*, 2011).

The locomotion and feeding behavior of the two GALS in captivity was studied. It was found out that the peak level of locomotion actually occurred at 23: 00 – 24:00 GMT while the feeding period was from 21:00 – 2: 00 GMT. Hence feeding of snails should be done late in the night (8:00pm) making the feed to be fresh at the time of presentation. The study on the impact of management systems of GALS revealed that snails collected from the wild had better flesh nutritional values than snails from domesticated farms. However, the mineral composition and the antinutrient properties of the flesh were not significantly affected by the management system.

Table 22: Measurements of ovotestis of different land snails commonly found in Abeokuta*

Snails Species	Weight (g)	Length (cm)	Width (cm)	Lobe number	Lobe length (cm)	Lobe width (cm)	Follicle number per lobe
A.marginata	0.34 ± 0.02^{a}	2.29 ± 0.11^{a}	0.94 ± 0.04^{a}	4	0.7	0.5	27
A.achatina	0.31 ± 0.03^{a}	1.86 ± 0.15^{b}	0.59 ± 0.04^{b}	6	0.4	0.3	39
A.fulica	0.12 ± 0.02^{c}	1.15 ± 0.11^{c}	0.42 ± 0.05^{c}	3	0.2	0.1	19
L.aurora	0.24 ± 0.02^{b}	1.41 ± 0.07^{c}	0.24 ± 0.04^{d}	4	0.3	0.2	18

*Mean values in each column with the different superscripts are significantly different ($p<0.05$).
Source: Idowu *et al.* (2006)

4.5 Earthworm

I was introduced to the earthworm world by that great scientist and teacher per excellence, Late Prof. V.L.A. Yoloye. As my project supervisor at the then Ondo State University, Ado-Ekiti, he encouraged my initiative to look at the earthworm found in some selected towns in the then Ondo state. This was the beginning of my attachment to earthworms. I however had a break for so many years while focussing on the African Pest grasshopper, *Zonocerus variegatus*. Earthworms are soil invertebrates that play a key role in recycling organic matter in the soils (Satchell, 1967). They are also 'ecosystem engineers' as they actively redesign the physical structure of the soil environment by their activities of ingesting soil litter and soil particles, depositing casts on the soil surface and translo-

cating soil particles while their gut, within which many changes take place have been described as 'natural bioreactors'. Results of various studies have revealed that earthworms have the capacity to increase the beneficial microbial diversity in the material it excretes to 1000 times that of the surrounding soil (Savin *et al*., 2004).

The first thing that was on my mind on entering this campus in 2001 following the relocation of the campus from Isale-Igbein/Isabo campus was if there was any exploratory survey of the fauna of the 10,000 hectares of land before the commencement of the destruction of the then natural forest. Why? It has been observed that the conservation of the natural fauna of a land mass has significant possible effect on the soil structure and fertility as we see later in this presentation. In view of this, our first priority was to have a comparative analysis of the fauna population in the soil of the University of Agriculture, Abeokuta (Idowu *et al*., 2003). In the light of this, we embarked on a preliminary survey and found out that soil micro and macro fauna namely; earthworms, nematodes and protozoa were abundant in all the soil sampling locations examined on the campus of the University of Agriculture, Abeokuta irrespective of the soil characteristics (Table 23). Analysis of the result showed that temperature and pH of the soil samples had no significant effect on the distribution and abundance of the fauna found. However, the organic matter content of the soil had a profound effect on the fauna popula-

tion (Idowu *et al* 2003).

We observed also that there were two groups of soil based on their organic content. The first group consisted of soil samples from fallow land, cultivated land, arboretum, refuse dump, students' hostel and student centre with high organic matter content and the second group comprised of the petrol station, works and services station, river bank, poultry pen and the clinic with low organic matter content. As expected, there was a positive correlation between the numbers (population) of fauna collected and soil organic matter contents.

The earthworms collected belong to four previously identified species of anecics namely *Keffia proxipora* Clausen (Segun and Owa, 1990), *Hippopera nigeriae* (Taylor, 1949), *Millsonia nigra* (Beddard, 1894) and the common *Libyodrillus violaceous* Clausen (Beddard, 1894). Except for *K. proxipora,* which is an exotic species from the eastern and northern banks of the river Niger (Segun and Owa, 1990), all the others are native species of western region of Nigeria. *K. proxopora* could have been introduced to the soils of Alabata as a result of cattle importation.

The profound positive effect of earthworms on soil properties influenced the next stage of researches carried out by my team to examine, in comparison, the distribution of microflora and microfauna in the gut of earthworm species, soil,

fresh and stored earthworm casts from the soils of the University of Agriculture, Abeokuta with a view to establishing a proper database necessary for building an ideal framework for the use of earthworms in organic agriculture in the University.

The results of the study showed that similar organisms were found in the soil, gut sections and castings of earthworms (Table 24a &b) (Idowu *et al*., 2005; 2007). The great similarity in the micro-organisms identified in soil samples and those identified in the various gut sections of earthworm implies that the earthworm ingest with soil, detritus micro-organisms which might be of dietary requirement (Idowu *et al*., 2005). Nematodes were not found in the casts, mid and hind gut sections of the earthworms collected. This was in confirmation of previous reports that earthworms and their microflora are able to destroy nematodes during their passage in the earthworm's gut (Savin *et al*., 2004).

The result of total aerobic and anaerobic count of micro-flora obtained from soils, earthworm castings, gut sections and gut contents of earthworms indicated that total numbers of micro -organisms were higher in castings and gut sections than in the un-ingested soil samples (Table 25). This is in agreement with previous reports that the numbers of microorganisms contained in the ingested materials increased tremendously (100% increase) while passing through worm's gut (Daniel and Anderson, 1992; Pederson and Hendrickson, 1993). The result

of our studies also showed that the worm's gut and its content also had higher moisture and total nitrogen contents than the soils. Counts were higher in fresh earthworm casts than in the casts collected after two weeks (Table 25). Earthworms have been shown to greatly influence the chemical, physical and biological properties of the soil they inhabit (Tiwari and Mishra, 1993). Our findings reinforce the concept that the earthworm gut might be a specialized microhabitat of enhanced microbial activities in soils (Karsten and Drake, 1995).

Several reports on analyses of worm castings, when compared with the parent soils, have revealed significant increases in colony forming units of micro-organisms especially higher bacterial counts in earthworms than in soils (Lee, 1985). The hindgut of *Libyodrillus violaceous* had the highest bacterial, protozoal and yeast counts as well as total viable counts of microflora (Table 23) (Idowu *et al*., 2008). This could be because *L. violaceous* is an indigenous worm while the other worms identified in this study are known to be exotic species to Abeokuta (Idowu *et al*., 2003). Studies have shown that the conservation of indigenous invertebrate biodiversity should be an integral part of land management strategies in the humid forest zones, if the goal of increased crop-yield sustainability is to be realized (Lavelle, 1996; Lavelle *et al*., 1998). Invasion of cleared forest by exotic species has been shown to have adverse consequences for soil structure (Barros *et al*., 1996).

The microbial counts of earthworms residing in the refuse dump area were highest in the sampling locations (Table 25). Earthworms collected from the cultivated farmland recorded the least counts (Idowu, 2005). The refuse dump area in the University campus is made up of monthly agricultural wastes that are rich in organic matter, which earthworms and micro-organisms can make use of for their growth and multiplications. The arboretum recorded the next highest numbers of microflora. This area is usually shaded and characterised by cool, undisturbed soil profile with relatively low temperature, a combination that is ideal for earthworms and micro-organisms alike. On the other hand, the cultivated land area is open, frequently disturbed by human activities and generally not a favourable environment for soil flora and fauna hence, the lower numbers of micro-organisms. Also, the excessive use of chemical fertilizers which characterises modern farming could also contribute to the low microbial loads observed in this location. Most changes in agricultural technology have ecological effects on soil organisms that can affect higher plants and animals, including man.

Table 23: Counts of microflora and microfauna in gut sections of earthworm species

	Bacteria	Moulds	Yeasts	Protozoa	Nematodes	Total viable counts
Keffia proxipora						
Fore gut	0.42a	0.03a	0.37a	8.00a	1.33b	0.80a
Mid gut	0.77b	0.03a	0.53abc	12.67abc	0.00a	1.30b
Hind gut	1.03bc	0.04a	0.70cd	24.00cd	0.00a	1.73cd
Libyodrillus violaceous						
Fore gut	0.87bc	0.04a	0.63bcd	10.67abc	1.33b	1.50bc
Mid gut	1.07cd	0.04a	0.83de	18.67abcd	0.67ab	1.90d
Hind gut	1.43e	0.03a	0.93e	28.00d	0.33a	2.37e
Hippoporera nigereae						
Fore gut	0.80bc	0.03a	0.43ab	8.67ab	0.67ab	1.27b
Mid gut	0.97bc	0.03a	0.83de	12.67abc	0.00a	1.63cd
Hind gut	1.30de	0.03a	0.93e	23.00bcd	0.00a	2.23e

Counts of microflora and total viable counts are in the order of 10^4 $cfu^{-1}ml$
Counts of protozoa and nematodes were taken as actual numbers of fauna observed
Mean values having the same latter in the same column are not significantly different at a level $P < 0.05$
Source: Idowu *et al* 2005

Table 24a: Distribution of isolated bacteria in the soils, casts and gut sections of *Libyodrilus violaceous*

Isolate	Sampling site	Un-ingested soil	Fresh cast	2 wks	Foregut	Midgut	Hindgut	Gut content
Staphylococcus aureus	A	+	+	+	+	+	+	+
	C	+	+	+	+	+	+	+
	R	+	+	+	+	+	+	+
Bacillus spp.	A	+	+	+	+	+	+	+
	C	+	+	+	+	+	+	+
	R	+	+	+	+	+	+	+
Pseudomonas aeruginosa	A	+	+	+	-	-	-	-
	C	+	+	+	+	-	+	-
	R	+	+	+	-	+	+	-
Streptococcus mutans	A	+	-	-	+	+	+	-
	C	+	+	+	+	+	+	+
	R	+	+	+	+	-	+	+
Clostridium spp.	A	+	+	+	+	+	+	+
	C	-	-	-	-	-	-	-
	R	+	-	+	-	-	-	-
Spirocheata spp.	A	+	+	+	+	+	+	+
	C	-	-	-	-	-	-	-
	R	-	-	-	-	-	-	-
Azotobacter spp.	A	-	-	-	-	-	-	-
	C	+	+	+	+	+	+	+
	R	-	-	-	-	-	-	-
Micrococcus spp.	A	+	+	-	+	-	+	-
	C	-	-	-	-	-	-	-
	R	+	+	+	+	+	+	+
Acinetobacter spp.	A	-	-	-	-	-	-	-
	C	-	-	-	-	-	-	-
	R	+	+	+	+	+	+	+
Halobacterium spp.	A	-	-	-	-	-	-	-
	C	+	-	-	-	-	-	-
	R	+	-	-	-	-	-	-

Legend: A-arboretum. C-cultivated land. R-refuse dump
Source: Idowu *et al* 2003

Table 24b: Distribution of isolated fungi in the soils casts and gut sections of *Libyodrilus violaceous*

Isolate	Sampling site	Un-ingested soil	Fresh cast	2 wks	Foregut	Midgut	Hindgut	Gut content
	A	+	+	+	-	-	+	-
Aspergillus spp.	C	+	-	-	-	-	-	-
	R	+	-	-	-	-	-	-
	A	-	-	-	-	-	-	-
Pytium spp.	C	+	+	-	+	-	+	-
	R	+	+	-	+	-	-	-
	A	-	-	-	-	-	-	-
Penicillium spp.	C	+	-	-	+	+	-	-
	R	+	-	-	+	+	-	-
	A	+	+	-	+	-	+	-
Fusarium spp.	C	+	-		-	-	-	-
	R	+	-	+	-	+	-	-
	A	+	-	+	+	-	-	-
Rhizopus spp.	C	+	+	+	-	+	-	-
	R	-	+	+	-	-	-	-
	A	+	+	+	+	-	+	+
Candida spp.	C	+	+	+	+	-	+	+
	R	+	+	+	+	+	+	+
	A	+	-	+	-	+	+	+
Zygosaccharo-myces spp.	C	+	+	+	-	+	+	+
	R	+	+	+	+	+	+	-
	A	-	-	-	-	-	-	-
Pichia spp.	C	-	-	-	-	-	-	-
	R	+	-	+	-	-	+	-
	A	+	+	+	+	+	+	-
Saccharomyces spp.	C	+	+	+	+	+	+	-
	R	+	+	+	-	+	+	+

Legend: A-arboretum. C-cultivated land. R-refuse dump
Source: Idowu *et al* 2005

Table 25: Parameters investigated in soils, casts and gut sections of *Libyodrilus violaceous*

Property	Sampling site	Uningested soil	Fresh cast	2 wks cast	Fore gut	Mid gut	Hind gut	Gut contents
pH	A	6	6.5	6.3	6.4	6.6	6.7	6.6
	C	6.4	6.5	6.6	6.5	6.7	6.7	6.6
	R	6	6.6	6.4	6.5	6.6	6.7	6.8
Moisture Content (%)	A	33.9	25.6	21.4	65.2	65.3	65.3	58.4
	C	33.8	25.4	23.3	65.5	65.4	65.5	58.7
	R	40.9	26.2	23.9	68.9	69.2	69.3	59.5
Temperature (^oC)	A	24.2	-	-	-	-	-	-
	C	24.6	-	-	-	-	-	-
	R	25.7	-	-	-	-	-	-
Nitrogen (%)	A	0.53	0.84	0.82	0.61	0.66	0.77	0.73
	C	0.51	0.79	0.75	0.63	0.65	0.67	0.69
	R	0.52	0.88	0.85	0.74	0.68	0.72	0.77
Organic matter (%)	A	3.72	-	-	-	-	-	-
	C	3.76	-	-	-	-	-	-
	R	3.9	-	-	-	-	-	-
Total aerobic counts (x 10^4 cfu / g)	A	3.1	3.4	3.2	0.5	1.4	1.9	3.5
	C	3	3.9	3.6	0.9	1.3	1.6	3.8
	R	3.6	4.6	4.2	1	1.2	1.7	4.8
Total anaerobic counts (x 10^4 cfu / g)	A	2.8	2	0.7	3.5	3.6	3.8	3.2
	C	2.4	1.8	0.9	3.9	3.9	3.7	3.3
	R	2.9	1.2	1.6	3.6	3.7	3.7	3.4
Total viable fungal counts (x 10^4 cfu / g)	A	2.6	1.8	1.8	1.4	1.4	1.5	1.7
	C	1.8	3.2	3	3.3	2.9	2.9	3.2
	R	3.5	3.8	3.7	3.7	3.6	3.8	3.7

Legend: A-arboratum, C-cultivated, R-refuse Source: Idowu *et al* 2005

The casting of earthworms collected had higher pH values than the surrounding uningested soil (Table 25) (Idowu *et al*., 2008) in confirmation of previous reports that casts are always more neutral than the soils from which the castings are formed (Idowu *et al*., 2003; 2007). Just how this is accomplished is unproved scientifically, although it is hypothesized that the waste and soil, in passing through the intestine is neutralized by its secretions and by the ammonia excreted by the worm (Scheu, 1987). The pH of the casts increased further with storage, although not significantly compared with the fresh castings. The bacterial counts of the casts also increased with storage when compared with fresh casts and soil samples. These findings could represent strong justification for the use of earthworm casts to improve soil fertility. The substitution of vermicast for high-density chemical fertilizers will reduce nutrient loss with run-off. This has wide ranging implications for farmers and agriculturists. Edwards and Bates (1992) found that earthworms increased significantly in number, growth rate and yields of plant growing on inoculated sites. Gross production doubled in New Zealand, a region that historically did not have earthworms when European species were introduced.

Total soil nitrogen analysis of earthworm castings in comparison with undigested soil revealed that they are richer in nitrogen than surrounding soil (Table 25). Thus, there appears to

be a sort of symbiotic association between earthworms and soil microflora resulting in improved soil condition expressed as high total nitrogen content. Previous studies have also reported similar trends with about three times more calcium, several times more nitrogen, phosphorus and potassium (Mulongiy and Bedoret, 1989). This could be very important for soil fertility using vermicompost. A wide variety of microflora and fauna were isolated from soil, casts and earthworm gut in this study. Many of the isolated species have also been found in similar studies (Daniel and Anderson, 1992; Kersten and Drake, 1995).

It is known that earthworm-produced compost (vermicompost) dramatically increases germination and growth in many plants. Adding only 5% of the compost to commercial growing media (95%) can significantly increase plant growth (Edward and Bohlen, 1996). The present study has also further demonstrated that the guts of earthworms are conducive for proliferation of microflora. Earthworms are ideal managers whom man can explore to maximise growth of aerobic bacteria for waste processing. This is an important characteristic that could be employed in the use of earthworms as biological agents for the improvement of soil fertility. Farm residue can be processed *in-situ* by the beneficial soil bacteria which are farmed by the earthworms hatched from the cocoons in the vermin-castings. Where the original earth-

worms are not present in sufficient quantities, inoculation of the vermi-casting may be necessary. The importance of macrofauna to the promotion of tropical soil fertility has been stressed (Lavelle *et al*., 1998). The distribution, protection and stabilization of organic matter, the genesis of soil structure (maroaggregates), humification, the release of immobilized N and P, the improvement of drainage and aeration, and the increase in exchangeable cations have been demonstrated in soils modified by termites and earthworms (Mulongoy and Bedoret, 1989; Lavelle *et al*., 1998).

Satchel and Martin (1984) found direct correlation between microbial population and enzyme activity. Microbes such as *Pseudomonas* spp., *Bacillus* spp. and *Aspergillus spp.* isolated in this study are known to mineralize phosphate. Vinotha *et al*. (2000) observed that increased amount of inorganic P released during cast deposition was related to and preceded by increased microbial and phosphate activity. High P_2O_5 content in cast support the phosphate availability which is required for growth of root, microbial enhancement and in turn, may help drive biological nitrogen fixation. Since the emphasis is now on organic matter, rather than organic fertilizer, for the improvement of soil fertility, there is the need to explore the potentials of earthworms in soil improvement especially in tropical Africa where the practice of vermicompost is virtually non-existent.

Most African soils are naturally rich in nutrients and we had a culture of rejuvenating our soil back to its fertile form after several uses. The vast abundance of earthworms in our soils especially during fallow has contributed significantly to richness of our soils and the quick recovery of its fertility. But once we accepted the *Oyinbo* man's tradition of applying inorganic fertilizer to our soil, we started the process of destroying the fertility of the African soil. Several works in our laboratory have shown that inorganic fertilizer causes reduction in the population of earthworm and sometimes wiping out of the whole community of earthworms in the soil. Recently we started celebrating organic farming because *oyinbo* man brought it to us. But this is a practice very common to our fore-fathers and we are never proud of what is ours.

Hyperiodrilus africanus holds great potential for use in vermicompositing (Edema *et al*., 2009). This was observed when a 30-days inoculation experiment of this earthworm into sterile soil along with isolated microflora significantly increased soil organic matter content as well as nitrogen, phosphorus and potassium contents. The organic matter content of soil sample from cultivated land increased from 3.76% to 48.29% in samples inoculated with *Rhizopus oligosporus* and earthworms within 30days, compared with un-inoculated compost which recorded a value of 23.80 after 180 days (Edema *et al*, 2009).

Our recent work on the physiology of indigenous earthworm species found in the sawmill industries is the first to be so reported (Bamidele *et al*., 2014). In the study, we observed a higher earthworm population density in the soils of major sawmills of Abeokuta when compared to the soil of the control site (Table 26) (Bamidele, 2014). The reports also covered the gut microbial load (Table 27a), microbial diversity (Table 27b) and the levels of digestive enzymes in the gut of earthworm species of sawmill origin (Table 28). Enzyme activity, of the various factors is influenced by type of food available to the earthworm (Parthasarathi and Ranganathan, 2000). The variation in cellulase activities recorded in the gut of *E. eugeniae* from the control site to those from the study sawmills was therefore associated with their ecological categories and feeding habitat. The earthworms of the control site feed mainly on leaves and tender stem litters while those from the study sawmills feed mainly on sawdust particles incorporated in the soils. Sawdust is made up of three major components; cellulose, hemicelluloses and lignin (Erikson *et al*., 1990) with lignin being the most recalcitrant and protects the cellulose and hemicellulose from enzymatic attack by some microorganisms (Bonnarme and Jeffries, 1998). The recalcitrant nature of lignin in sawdust which forms the bulk of organic substrate in the sawmill soils could as well have resulted in the low activities of cellulase recorded in the gut of *Eudrilus eugeniae* from the study sawmills as compared to those of the

control site. Shi *et al*. (2007) reported a reduction in the cellulose activity in the gut of earthworms treated with deltametrine pesticides. Therefore, several pollutants, including wood preservatives from sawmilling activities could as well be responsible for the low cellulase activities in the gut of the earthworms.

Higher microbial population and diversity were also observed to be a compensation for low cellulase activities in the gut of earthworm species (Bamidele *et al*., 2014). More microbial flora was observed in the gut of earthworms of the sawmills with lower cellulase activities than in the gut of earthworms from the control site with higher cellulase activities. Bamidele *et al*. (2014) therefore concluded that the difference in microbial species (bacteria and fungi) isolated from the gut of earthworms from the control site and those of the study sawmills suggests that the microhabitats of the earthworm guts were carefully selected to suit their environment and also compen-

Table 26: Earthworm species diversity and abundance (earthworm / m^2) in the study locations, Abeokuta Nigeria

	Earthworm Species	Earthworm Population
Control	*Eudrilus eugeniae,* (Kinberg,1866) *Dichogaster modiglani* (Rosa,1896) *Alma millsoni* (Grube, 1855)	96[d]
Kotopo sawmill	*Hyperiodrilus africanus,* (Beddard,1890) *Eudrilus eugeniae, Libyodrilus violaceous* (Beddard,1891)	140[cd]
Sapon sawmill	*Hyperiodrilus africanus, Eudrilus eugeniae, Libyorilus violaceous, Dichogaster modiglani*	516[a]
Isale Ake sawmill	*Hyperiodrilus africanus*	264[bc]
Lafenwa sawmill	*Libyorilus violaceous*	364[b]

******Mean values of earthworm population having the same superscripts are not significantly different *(P* >0.05) Source: Bamidele *et al*., 2014

Table 27a: Gut microbial load count (x 10^3 cfu) of the earthworm species from the study locations

Locations	Earthworm species	Bacteria	Fungi
Control site	*Eudrilus eugeniae*	17.5±0.1*	4.5±0.1*
Kotopo sawmill	*Eudrilus eugeniae*	28.5±0.1*	96.0±0.1*
Sapon sawmill	*Eudrilus eugeniae*	54.0±0.1*	10.0±0.1*
Isale-Ake sawmill	*Hyperiodrilus africanus*	82.5±0.1	11.0±0.1
Lafenwa sawmill	*Libyorilus violaceous*	97.0±0.1	7.0±0.1

*The mean (± Standard Error) difference is significant at $P \leq 0.05$. (N = 3)
Source: Bamidele *et al*., 2014

Table 27b: Microbial diversity in the gut of the earthworm species from the study locations

Sample locations	**Organisms isolated**		
	Earthworm species	Bacteria	Fungi
Control site	*Eudrilus eugeniae*	*Serratia spp.*	*Saccharomycetes cerevisae* *Candida albicans*
Kotopo sawmill	*Eudrilus eugeniae*	*Proteus spp.* *Streptococcus spp.* *Aerobacter aerogenes*	*Penicillium spp.* *Cladosporium spp.* *Fusarium spp.*
Sapon sawmill	*Eudrilus eugeniae*	*Serratia spp.* *Proteus spp.* *Salmonella spp.* *Streptococcus spp.*	*Cladosporium spp.* *Aspergillus flavus* *Penicillium spp.*
Isale-Ake sawmill	*Hyperiodrilus africanus*	*Streptococcus spp.* *Aerobacter aerogenes* *Micrococcus spp.*	*Aspergillus flavus* *Penicillium spp.* *Fusarium spp.*
Lafenwa sawmill	*Libyorilus violaceous*	*Serratia spp.* *Proteus spp.* *Salmonella spp.* *Streptococcus spp.*	*Aspergillus flavus* *Aspergillus niger* *Mucor spp.*

Source: Bamidele *et al*., 2014

Table 28: Digestive enzymes in the gut of earthworm species from the study locations

Sample	Earthworm species	Cellulase activity (mg/g)	α – Amylase activity (mg/g)	β – Amylase activity (mg/g)	Protenase activity (mg/g)	Lipase activity (mg/g)
Control site	*Eudrilus eugeniae*	48.67±0.02*	8.86±0.02*	8.14±0.04*	8.67±0.03*	1.81±0.01*
Kotopo sawmill	*Eudrilus eugeniae*	38.92±0.03*	12.11±0.06*	10.92±0.02*	8.92±0.01*	1.68±0.00*
Sapon saw-mill	*Eudrilus eugeniae*	42.66±0.04*	10.96±0.03*	10.16±0.03*	8.15±0.02*	1.73±0.01*
Isale ake sawmill	*Hyperiodrilus africanus*	40.14±0.10	11.68±0.02	10.56±0.01	8.06±0.02	1.62±0.01
Lafenwa sawmill	*Libyorilus viola-ceous*	44.26±0.03	10.12±0.03	9.62±0.03	8.44±0.04	1.45±0.02

*The mean (± Standard Error) difference is significant at $P \leq 0.05$. (N = 3)
Source: Bamidele *et al*., 2014

The study on the level of heavy metal pollution in the earthworm, plants and soils of major sawmilling industries in Abeokuta revealed that earthworm (*E. eugeniae*), plants and soils from the sawmills had higher concentrations of Pb and Cd when compared to the samples collected from the control site (Bamidele *et al*., 2015). This can be attributed to anthropogenic influence. Most of the sawmilling machines engines run on fuel (diesel or petrol) while others depend on standby power generating sets at various locations within sawmills. There is also the factor of fuel spills from generating sets and improper disposal of spent oil. These and coupled with pollution from wood preservatives and vehicular exhaust could be responsible for the higher concentration of Pb and Cd in the earthworm, plants and soils from sawmills. The activities of the stress enzymes (superoxide dismutase, glutathione peroxidise and catalase) in *E. eugeniae* was also observed to be influenced by pollutants entering sawmills from the neighbourhood. The results also showed that the earthworm, *Eudrilus eugeniae* from sawmills expressed more protein bands than those of the control site (Bamidele *et al*., 2015). This expression of more protein bands in *E. Eugeniae* was suggested to have resulted from the physiological adaptations of the earthworms to the pollutants including heavy metals from sawmilling activities. We were able to conclude that exposure to constant pollutants including heavy metals by earthworm species could lead to the production of new species as reported

by Hamdan and Magdy (2010). They observed that changes in protein banding patterns in animal species could be as a result of gene mutation. Kordafshari *et al*. (2010) also submitted that the appearance of new protein bands is based on a mutational event at the regulatory system of unexpressed gene(s) that activate them.

4.6 **Studies on Rat physiology**

POLLUTION STUDIES

It is not the number of cars on our road that terrifies me but the impact of their exhaust on the physiology of men and women especially those who ply their trades on major highways either as beggars or marketers of food items or wares that gives me serious concern. It is becoming a serious concern now that we import automobiles that have almost outlived their usefulness. As a young Nigerian on the street of La-

gos, you see signs or labels such as "off the roads" on some cars and trucks and you laugh. The situation now is far more horrible than then and I have not seen off the road on any automobile. Not too long ago, the government in Ogun State introduced a scheme to check the *off the road* syndrome but alas it was just for mere cash collection. The worst of cars are given freedom of passage once they are able to pay N1000.

Research studies were carried out using rats to assess the impact of exhaust fumes of automobiles plying major busy roads in Abeokuta and Lagos. This study gave me opportunity to see that Nigerians are accommodating, supportive and protective of research programmes when they are properly briefed. After some weeks, aggressive behaviour such as tooth chattering, threat posture, boxing position, leaping and biting were observed among rats placed in close proximity to busy roads at Oke-Ilewo and Ijemo while the rats at the arboretum of the federal University of Agriculture, Abeokuta far away from traffic movement showed no significant change in their behaviour. In addition, baldness and low food intake were observed among rats at Oke-Ilewo and Ijemo roads (Ajayi 2011). Are these behaviours common on our roads? The fumes from the automobiles also had implication on the digestive system of the rats, gut microbial flora of rats exposed to fumes from vehicular exhaust were significantly lower to those in the control recorded for control rats.

Also, concentrations of some heavy metals tested like (Fe^{2+}, Mn, Zn, Pb and Co) (Table 29) were significantly higher in the lungs, heart, and liver tissues of the rats exposed to vehicular fumes. A higher concentration of white blood cell, mean corpuscular haemoglobin, glucose, total cholesterol, triglyceride and inorganic substances (K, Cl, Ca, $HC0_3$) were recorded in the blood of rats along Oke-Ilewo and Ijemo roads compared to those rats in the control centre (Tables 30a and 30b).

Olayinka (2011) used earthworm as bio-index of soil heavy metal pollution. This was done to assess the impact of industrial wastes on earthworm found in the soil. The study confirmed that the earthworm *Hyperiodrilius africanus* can serve as a bio-indicator in polluted environment. Presently, work is on to assess the impact of these industrial wastes on rats. Heavy metal concentrations in earthworm, soil and plant were observed to significantly decrease with increasing distance from the factory. The concentrations of these heavy metals in the soil, earthworm and plant samples were significantly higher around the cement factory compared to those of the control site. The microbial load (bacteria and fungi) was also observed to significantly increase with increasing distance from the cement factory with the control site recording a significantly higher microbial load. The study therefore concluded that the decrease in bio-accumulation of heavy metals in soil, earthworm and plant samples with increasing distance away from

the cement factory could serve as a possible bio-index of heavy metal pollution.

Table 29: Concentrations of heavy metals (mg/kg) in the Lungs, heart and liver of Albino rats placed at the locations in Abeokuta, Nigeria

Locations	Zn	Pd	Co	Mn	Total
			Lungs		
UNAAB Forestry Nursery	172.90^{c}	Nil	18.03^{c}	25.40^{c}	216.33
Oke Ilewo Road	210.23^{b}	29.87^{a}	34.50^{b}	32.97^{b}	307.57
Ijemo Road	312.97^{a}	71.00^{b}	45.17^{a}	150.00^{a}	579.14
			Heart		
UNAAB Forestry Nursery	125.20^{c}	Nil	8.23^{c}	24.03^{c}	157.46
Oke Ilewo Road	155.80^{b}	Nil	11.10^{b}	27.43^{b}	194.33
Ijemo Road	225.80^{a}	50.07^{a}	18.07^{a}	29.05^{a}	322.99
			Liver		
UNAAB Forestry Nursery	87.87^{c}	Nil	4.37^{c}	5.77^{b}	98.01
Oke Ilewo Road	102.70^{b}	Nil	5.97^{b}	11.90^{b}	120.57
Ijemo Road	112.13^{a}	4.07^{a}	8.60^{a}	30.55^{a}	155.35

^{abc}Mean values in the same column having the same superscript are not significantly different ($p > 0.05$) Source: Ajayi 2011

Table 30a: Haematological parameters of Albino Rats placed at different locations in Abeokuta, Nigeria

Parameter	UNAAB forestry	Oke-Ilewo Road	Ijemo Road
PVC (%)	28.67 ± 1.6[a]	30.67 ± 1.0[a]	32.67 ± 1.8[a]
RBC × 10^6/ mm^3	5.2 ± 0.2[b]	4.6 ± 0.1[a]	5.4 ± 0.1[b]
WBC (cm^{-3})	4533.3 ± 389.6[a]	9200.0 ± 1182.0[b]	9816.0 ± 1488.9[b]
Hb × 10^{12}g/dl	4.58 ± 0.2[a]	5.35 ±0.1[b]	11.02 ± 0.6[b]
MCH (g/dl)	21.1 ±0.2[a]	19.5 ± 0.6[b]	21.1 ± 0.3[b]
MCHC (pg)	0.34 ± 0.0[a]	0.34 ± 0.0[a]	0.34 ± 0.0[a]
MCV (fl)	6.27 ± 0.1[a]	5.74 ± 0.2[b]	6.26 ± 0.2[b]

Each value represents mean ± Standard deviation
[abc]Mean values in the same row having the same superscript are not significantly different (p>0.05).PCV - Packed cell Volume, RBC - Red Blood Cell, WBC - White Blood Cell, Hb – Haemoglobin, MCH - Mean Cell Haemoglobin, MCHC - Mean Cell Haemoglobin Concentration, MCV - Mean Cell Volume. Source: Ajayi 2011

Table 30b: Blood Chemical parameters of Albino Rats placed at the locations in Abeokuta, Nigeria

Locations	Na^+ (mmol/L) Mean±SE	K^+ (mmol/L) Mean±SE	Cl^- (mmol/L) Mean±SE	Ca^{2+} (mmol/L) Mean±SE	HCO_3^- (mmol/L) Mean±SE	Total Protein (g/L) Mean±SE	Glucose (mg/dl) Mean±SE	TotalCholesterol (mgl/dl) Mean±SE	Triglyceride (mg/dl) Mean±SE
Oke Ilewo Road	149.0±2.7[b]	6.3±0.7[a]	104.0±5.1[a]	9.9±0.1[b]	23.3±1.8[a]	63.6±2.8[a]	72.5±6.7[a]	135.9±15.7[a]	95.3±14.8[a]
Ijemo Road	145.3±2.4[b]	4.2±0.7[a]	89.1±7.7[a]	9.2±0.3[a]	25.0±1.7[a]	53.0±3.8[a]	78.1±8.9[a]	111.2±14.8[a]	67.2±18.8[a]
UNAAB Forestry	69.1±7.7[a]	4.3±1.1[a]	99.3±2.6[a]	9.1±0.2[a]	24.7±1.8[a]	53.6±3.9[a]	69.1±7.7[a]	97.9±3.2[a]	67.1±14.1[a]

Source: Ajayi 2011

4.7. DIABETES STUDIES ON RATS

Diabetes Mellitus (DM) is a chronic metabolic disorder of the pancreatic beta cells in which insulin production is either lost or impaired. It is a disease characterized by an abnormally high level of blood glucose and by the excretion of excess glucose in the urine. This condition increases the blood glucose concentration to above 160mg/dl of blood from a normal fasting blood glucose concentration of 80-120mg/dl of blood in humans.

As at the year 2011, the World Health Organization (WHO) and the International Diabetes Federation (IDF) put the global prevelence of DM at 8.3%, while it is projected that 552 million people (9.9%) will be diabetic by the year 2030 (IDF Diabetes Atlas, 2011). Nigeria has the highest number of people living with DM in Africa (3 million) accounting for a national prevalence of 4.04%.

Each year, about three million people find out they have diabetes and probably have had the disease for several years before it was diagnosed. Some 4.6 million people between the ages 20-79 years died from diabetes in 2011, accounting for 8.2% of global all-cause mortality. Notably, the total deaths from diabetes is projected to rise by more than 50% in the next 10 years, and to increase by over 80% in upper-middle income countries. It is also alarming to state that about 80%

of diabetes deaths are now occurring in low- and middle-income countries.

TYPES OF DM

There are three major types of diabetes mellitus; type 1, type 2 and gestational diabetes (International Diabetes Federation, 2011) Type 1 diabetes is caused by an autoimmune destruction of the insulin – secreting beta cells in the pancreas (Lubert, 1995). It is characterized by a partial or complete loss, of insulin producing beta cells and therefore patients require daily injection of insulin. This type of diabetes usually develops during childhood, adolescence or during early adulthood and affects approximately 5- 10 % of all people with diabetes (Dodda and Ciddi, 2014). International Diabetes Federation (2011) reported that Type 1 diabetes affects 78,000 children annually. Although the disease affects only a small percentage of all people with diabetes, it is associated with a greater prevalence of premature complications and mortality than any other forms of the disease (Harris, 1995).

Type 2 Diabetes Mellitus is the most common type of diabetes mellitus affecting 90-95 % of people who develop diabetes and it occurs as a result of loss of insulin responsiveness in its target tissues (El-Wakf *et al.*, 2011). Worldwide, about 120 million people suffering from Type 2 diabetes are able to produce insulin but the liver and muscle cells are resistant to its action

and most people with type 2 diabetes find out about their diabetic condition after the age of 40, although the numbers of young people, including teenagers, with type 2 diabetes are growing rapidly (Harris, 1995). Increasing age, obesity, diets rich in high glycemic index foods and physical inactivity are risk factors that may enhance the chances of someone developing type 2 diabetes mellitus.

Gestational diabetes (GDM) is defined as a carbohydrate intolerance that normally develops during the 24th through to the 32nd week of pregnancy. This condition affects 2 – 5% of all pregnant women and is the most common disease affecting pregnancy (Harris, 1995). Hormones produced by the placenta oppose the action of insulin in order to provide food for the growing baby. In gestational diabetes, hormones cause elevated blood glucose levels and can cause the body to grow to a size larger than normal. This increases the risk for a difficult delivery (Kjosi and Buchaman, 1999).

TREATMENT AND MANAGEMENT

The most common method of management of DM is the administration of insulin and other hypoglycemic agents such as sulphonlyreases and biguanides. However, complete cure of the disease has been eluded medical experts for centuries, and the quest for the development of more effective antidiabetic/ hypoglycemic agents is being pursued relentlessly.

HERRBAL MEDICINE: A PROMISING ALTERNATIVE

According to report by the World Health Organization (WHO) about 80% of people living in developing countries depend on orthodox medicine. Many herbal products including several minerals supplements and metals have therefore been prescribed for the treatment of DM. Herbal formulations alone or in combination with oral hypoglycemic agents sometimes produce good therapeutic responses in some resistant cases where modern medicines alone have failed.

In 2005, the Diabetes Research Group of the Department of Biological Sciences, University of Agriculture, Abeokuta, Nigeria, started a series of studies to investigate the hypoglycemic and ameliorative potentials of indigenous medicinal plants for the treatment of diabetes mellitus. The major crust of our focus is to assess the efficacy of indigenous plants in ameliorating the pathophysiological complications of Diabetes mellitus. One major problem facing scientists, particularly in the developing countries as regards phytotherapy research on type 2 DM, is the availability of animal model for type 2 diabetes research. We therefore pioneered a study to induce a novel animal model of type 2 diabetes mellitus using food of high glycemic index (Adeyi *et al*., 2012).

Rats were induced by feeding the animals with food of high

glycemic index for 8 weeks. White bread which has glycemic index value of 70 was fed to the rats, while granulated sugar with glycemic index value of more than 100 was dissolved in the drinking water at a concentration of 1g/ml. Surviving rats after 8 weeks with blood glucose concentration of 200mg/ml were considered as food-induced type 2 model diabetic rats (Table 31).

The study presented a rat model of type 2 diabetes mellitus using food of high glycemic/low fat index with its consequent iono-regulatory disruptions, acute anaemia, hyperlipidemia (Table 32), nephropathy and hepatopathy (Adeyi *et al*., 2012).

Further studies were also conducted to investigate the ameliorative potentials of *Ficus exasperata* on food and alloxan induced diabetic rats (Adeyi *et al.,* 2012). Food and alloxan-induced rats were treated with various doses of *F. exasperata*. We found out that the extract was not only a more potent hypoglycaemic agent compared to the standard antidiabetic drug, glibenclamide, but it also ameliorated the pathophysiological complications of Diabetes mellitus such as iono-regulatory distruptions, oxidative stress and dislipidemia (Tables 33and 34) and various histopathological degenerations observed in the pancreas and kidney

Table 31: Glucose concentration of food and alloxan-induced diabetic rats

Groups	Initial Glucose Concentration (mg/dl)	Confirmatory Glucose level (mg/dl)	Percentage Change	Blood glucose (2 weeks) (mg/dl)	Insulin Concentration (mmol/L)
Control	81.0±4.3 a	79.8±4.1 a	-2.31	80.1+2.4 a	12.13+1.2 b
AU	86.85±4.4 a	387.35±8.9 c	+346.0	393.23±3.1 c	3.57±2.6 a
FU	87.75±5.6 a	270.27±4.7 b	+208.0	233.19±2.2 b	16.05+2.9 c

AU=Alloxan-induced group
FU=Food-induced group Source: Adeyi *et al*., 2012

Table 32: Blood biochemical concentrations of food and alloxan-induced diabetic rats

Group	Total cholesterol (mg/dl)	Triglyceride (mg/dl)	HDL (mg/dl)	LDL (mg/dl)	LDL/HDL	CRI
Control	84.6±4.4a	69.2±1.7a	30.0±2.3b	58.6±3.6a	1.95±1.4a	2.82±2.3a
AU	123.1±2.4b	94.5±2.3b	15.8±2.5a	95.4±4.4c	6.04±1.6b	7.79±1.5b
FU	130.8±3.2c	100.3±2.9 c	15.3±3.5a	92.3±4.5b	6.03±2.4b	8.55±1.7c

AU=Alloxan-induced group
FU=Food-induced group
Source: Adeyi *et al*., 2012

Table 33. Blood chemistry of treated diabetic rats

Groups	Na+ (mmol/L)	K+ (mmol/L)	Ca2+ (mmol/L)	Total protein (g/L)	Urea (mg/dl)	Peroxidase activity (U/L)	Catalase activity (U/L)
Control	98.2±1.5a	7.8±3.3abc	2.4±2.5ab	93.9±1.5f	65.4±3.8e	1.052±2.7ab	0.631±2.3a
A1	102.3±1.4bc	7.2±2.4ab	2.2±1.9a	78.3±2.7bc	57.8±3.3cd	1.102±3.3bc	0.986±1.5bc
A2	106.8±2.9c	7.0±1.7a	2.6±4.4abc	80.1±2.5c	54.6±1.2c	1.003±2.8a	0.686±3.9a
A3	100.5±1.6b	7.9±2.7abc	2.5±3.6ab	83.5±3.6de	58.5±2.5d	1.103±2.5bc	0.860±2.2b
G	122.3±3.5e	10.0±1.9d	2.8±3.8bc	73.1±4.8a	46.8±1.3a	1.902±4.8e	1.158±2.4d
U	117.8±2.6d	19.8±2.4e	3.7±2.3d	75.7±2.9ab	48.8±1.4ab	1.853±1.5d	1.516±4.0e

ROUP A1= alloxan-induced rats that are treated with *F. exasperata* (100mg/kg)
GROUP A2= alloxan-induced rats that are treated with *F. exasperata* (200mg/kg)
GROUP A3= alloxan-induced rats that are treated with *F. exasperata* (300mg/kg)
GROUP G= alloxan-induced rats that are treated with glybenclamide (10mg/kg)
GROUP U= alloxan-induced rats that are not treated.
Source: Adeyi *et al*., 2012

Table 34. Plasma lipids of treated diabetic rats.

Group	Total cholesterol (mg/dl)	Triglyceride (mg/dl)	HDL (mg/dl)	LDL (mg/dl)	LDL/HDL	CRI
Control	84.6±3.4a	69.2±2.9a	59.84±2.4bc	38.6±3.9a	0.65±3.9a	1.41±1.5a
A1	108.5±3.6bc	73.2±3.4bc	66.94±4.6de	56.2±2.5b	0.84±2.5b	1.62±2.3b
A2	100.4±2.4b	74.5±3.8c	52.34±1.0b	63.0±4.7c	1.20±4.4d	1.92±2.5d
A3	106.7±2.3b	75.8±4.5cd	62.06±3.9c	59.8±1.4b	0.96±5.3c	1.72±3.8c
G	115.4±4.9d	86.3±2.4e	66.66±3.4d	66.0±3.5cd	0.99±2.4c	1.73±3.9c
U	123.1±2.6e	94.5±2.5f	46.60±4.5a	95.4±1.4e	2.05±3.5e	2.64±2.4e

Source: Adeyi *et al*., 2012

The group also carried out studies on the prevention of the food-induced non-obese type 2 DM animal model using local food condiments richly available in Nigeria. Rats were fed with food of high glycemic index incorporated with mushroom *Pleurotus pulmonarius* and supplemented with vitamins and minerals for 8 weeks (Table 35). Result showed that rats fed on the supplemented feed were not diabetic after 8 weeks as against rats fed on high glycemic index diet alone (Adeyi, 2012). These results show great promise for prevention of type 2 DM.

In 2015, the group presented a review of the effects of medicinal plants on the complications of Diabetes mellitus stating the components of the plants responsible for these effects and the possible mechanisms (Adeyi *et al*., 2015).

THE MISSING LINK IN TRANSLATIONAL DIABETES RESEARCH

Numerous other scientists in various academic and research institutions scattered all over the country have conducted studies towards discovering the therapeutic potentials of some of Nigerian indigenous herbs for the treatment of this metabolic disease. The important findings of such researches have been published in numerous reputable local and international journals and are also available on the internet.

Table 35: Blood glucose concentration of food-induced rats (mg/dl)

Group Code	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Confirmation Week	% Increase
A	80.6± 4.1 a	82.0± 2.3 a	79.6± 3.9 a	80.4± 4.8 a	82.2± 1.3 a	79.6± 3.1 a	81.2± 3.4a	80.1± 2.9 a	0
C1	80.4± 3.4 a	83.1± 4.6 b	89.8± 1.4 d	91.5± 6.6 d	98.7± 2.1 c	102.6± 5.2b	138.3± 2.6c	145.9± 2.4c	81.3
C2	82.8± 1.6 b	83.8± 2.9 b	86.2± 2.5 c	90.2± 4.5 c	98.7± 4.5 c	112.6± 1.3d	142.4± 2.7d	160.5± 1.5d	95.1
C3	80.3± 2.9 a	82.3± 1.1 a	83.5± 3.1 b	85.6± 2.4 b	97.7± 2.6b	109.5± 2.1c	117.8± 1.6b	121.2± 3.5b	51.3
C4	83.4± 2.3 c	89.5± 3.8 c	107.9± 4.6 e	122.9± 2.8 e	147.8±4.5d	209.2± 1.6e	212.7± 1.7e	231.3± 2.7e	178.3

Values are mean±S.E.M. n≤5
Values within a column having different superscripts are significantly different at p<0.05
A= Control
C1= Given Vitamin and mineral supplement
C2= Given Mushroom as supplement
C3= Given Mushroom and Vitamin/mineral supplement
C4= Given no supplement Source: Adeyi *et al*, 2012

However, a critical analysis of the Nigerian picture with regard to diabetes research reveals that researches on diabetes in Nigeria are fragmented, disjointed, non-coherent and unfocused. Our efforts on unravelling the medicinal potentials of our local herbs for the treatment of diabetes have so far been individualistic, haphazard, and lacking in direction towards a particular goal.

Also, important discoveries of these researches are lying fallow in books and journals on the shelves of our libraries and on the internet. The benefits that could flow from these researches are not being enjoyed by the over 1.7 million Nigerians suffering from the disease. Thus, we are like the proverbial people 'who are living close to the river and yet are dying of thirst'.

This situation is so because there exists a gap in translating the novel findings of many of such researches to benefits for diabetic suffferers. There is also the lack of awareness and sensitization on the immediate benefits of the research findings so that sufferers of the disease can benefit from results obtained from such studies. Therefore a Centre that will harness the findings of these and other such researches on DM and that will also fine-tune these basic researches with the aim of translating results obtained to the benefitts of DM sufferers will help to connect the "*thirsty to the river*".

In 2008, the FUNAAB diabetes group conceived an idea to establish a world class centre that will coordinate various researches on diabetes mellitus in the country and focus on the medicinal potentials of the numerous indigenous herbs that are abundant in Nigeria with a view to finding better and safer herbal formulations and more effective management medicines for the prevention and possible cure of diabetes mellitus. Today, we have the **Centre for the advancement of research in diabetes** (CARD), Nigeria as a registered entity under the able leadership of Prof. O.O. Akinkugbe and the inaugural lecturer of today as the project manager.

Honey Bee, *Apis melifera*

Worker Queen Drone

The honey bee, *Apis melifera* is a social insect domesticated for honey production and pollination activities. We investigated the nestling habits, species composition, morphological variations, body and gut microflora and the quality of honey produced by the honey bees from the wild (feral), modern and traditional beekeeping methods in the guinea and derived Savannah geo-ecological zones of Kwara State. The three beekeeping practices (honey hunting in the wild bee nests, modern and traditional reared bees) have the same distribution of microorganisms (moulds-Mucor sp, Aspergillus sp. and bacteria such as Staphylococcus and Bacillus) in the two ecological zones. Most of these microorganisms were known for nutrient synthesis and for the digestion of food plants which possibly enable the insects to adapt to varieties of plant hosts. However, the microbial load varied significantly and the wild habitat had the highest microbial loads in both ecological zones. (Ajao et al, 2013).

The proximate and chemical analysis of the honey samples from the three habitats (Tables 36 & 37) in both ecological zones were within the range recommended by National Agency for food and drug Administration in Nigeria (NAFDAC, 2004). The honey obtained from the wild bee colony had the highest concentrations of sugars and the protein in both ecological zones as against the expectation of the honey from modern bee colony whose bees are being additionally fed with sugar syrups (Ajao *et al*, 2014). Two reasons could be adduced to explain this observation. The high concentrations of the sugar could be as a result of wide foraging activities of the wild honey bees on varieties of plants as compared with the bees from modern and traditional beekeeping (Fasasi et al., 2007; Akinwale and Badejo, 2009). On the other hand, the high sugar and protein concentrations could have been the synergetic effects of the high microbial load of microorganisms in the gut of the bees from wild habitat since the honey is a product of the bees and these microorganisms have been implicated in the synthesis of carbohydrate and protein (Idowu and Edema, 2002). The relatively low moisture content in the honey from wild and traditional colonies is of advantage to this product. Apart from the fact that the high moisture content usually cause decrease in the protein content (Fakunle et al., 2009), the lower the moisture contents of the food component, the lower the susceptibility to microbial de-

terioration and higher keeping quality (Ajayi and Adedire, 2007). However, despite the high sugar and protein concentrations of the honey from wild habitat, the honey had least concentration of the ions. The significantly higher concentrations of the chemical ions in the honey from modern bee colony may not be unconnected to the mode of harvest of the honey from these colonies. Unlike wild and traditional colonies which are often been harvested by smoke which make the honey to be prone to contamination and loss nutrients, the colony in modern beekeeping uses protective clothing for the harvest without injury to bees and the hive products (Inah et al., 2006).

As the consumption of honey products is increasing in Nigeria, there is need for monitoring of these consumed hive products for nutritive values and heavy metals. Unfortunately, the large proportion of hive products in Nigeria today come from the wild (Lawal and Banjo, 2010).

Bee farming is one of the important means of reducing poverty and could serve as potential for employment among the youths in Nigeria. One of the major problems for the setting up of modern bee hive is the availability of a queen and therefore requires that for an apiary to be of a commercial value, the owner must have the knowledge of raising artificial queen.

Presently, we are conducting studies on the highly organised Osun State Apiary which has modern facilities for improving the quality and production of honey from bees and production of artificial of queen bees. Also, some of the undergraduate students from the Department are being encouraged to have their SIWES training programme at the apiary.

The results of this study have buttered the need to develop Nigerian modern bee hives patterned after the nature of the living tree cavities in the wild which we have discovered support the production of quality honey. Most of the present day modern bee hives in Nigeria are of foreign origin.

Table 36: The proximate Analysis of the Honey Samples in the Derived Savannah

Parameters	Wild habitat	Modern hive	Traditional hive
Moisture content (%)	20.25±0.10[b]	19.26±0.06[c]	22.09±0.01[a]
Honey density	0.52±0.02[a]	0.88±0.05[b]	0.60±0.01[a]
Dextrose (mg/g)	264±1.0[a]	236±1.50[b]	204±1.0[c]
Fructose (mg/g)	462±2.5[a]	436±2.5[b]	386±1.5[c]
Sucrose (mg/m)	8.72±0.02[a]	6.13±0.01[B]	3.03±0.53[c]
Crude protein (mg/m)	1.46±0.01[a]	1.34±0.04[b]	1.20±0.05[b]

Values with different letters in a row were sig at p<0.05 (SNK) Source: Ajao *et al*, 2012

Table 37. Chemical Analysis of Honey Samples in the Guinea Savannah

Parameters	Wild bees	Modern Reared bees	Traditional reared bee
Ph	4.21±0.01[b]	4.75±0.05[a]	4.27±0.25[b]
Magnesium (mg/g)	0.14±0.01[a]	0.19±0.05[a]	0.17±0.1[b]
Iron (mg/g)	16.01±0.15[a]	22.02±0.02[a]	17.02±0.01[a]
Phosphorous (mg/g)	2.04±0.01[b]	2.13±0.02[b]	2.19±0.05[b]
Potassium (mg/g)	1.02±0.01[c]	2.23±0.02[a]	2.38±0.05[a]
Sodium (mg/g)	1.38±0.01[b]	0.94±0.02[a]	0.93±0.05[b]
Zinc (mg/g)	0.88±0.01	0.57±0.01[b]	0.28±0.15[c]

Values with different letters in a row were sig at p<0.05 Source: Ajao *et al*, 2012

STUDIES ON FISH MAGGOT FOR FISH PRODUCTION

Insect provide a significant protein source for insectivores with values ranging from 34% in wax moth larvae to 80% of dry matter in cockroach and dragonfly (Dierердied, 1993). Result from our study revealed that housefly larvae are well utilized when used as an alternate source of protein in the diet of *Clarias gariepinus* as a source of protein in fish feed (Idowu *et al* 2003). It is remarkable to note that in the study fingerlings with higher dietary maggot inclusion (diets IV and V) converted their food better than those with lower maggot and no maggot inclusion (diets I and II) (Table 38). The study has demonstrated that the larvae of housefly can be used to promote the growth of fish and also utilization of maggot as a feed could serve as a means of reducing the population of adult *Musca domestica* which in turn gives rich source of dietary protein to the fish. The result of this study has also been adopted by the Animal Feed Resources Information system, Feedipedia (http://www.feedipedia.org/node/16352).

Table 38: Mean growth response and nutrient of *Clarias gariepinus* fingerlings fed on experimental diet containing housefly maggot

Dietary level of (HFMM)%	Average Wt. Gain	Average Length gain	Average Feed intake	Feed Con-version ratio	Protein efficiency ratio	Specific growth ratio	% fish mortality
0.0	3.90a±0.28	2.82a±0.11	4.75a±0.18	1.17a±0.08	1.83b±0.18	1.65a±0.09	15
12.5	1.54c±0.06	1.77a±0.11	3.53b±0.19	1.19a±0.09	1.07c±0.09	0.77a±0.04	10
25.0	2.66b±0.12	2.36a±0.13	3.00c±0.15	1.12a±0.06	2.05a±0.19	0.96a±0.06	15
50.0	2.55b±0.09	1.21a±0.09	3.49b±0.18	1.38a±0.11	1.69b±0.16	1.12a±0.08	10
100	1.33c±0.15	0.94b±0.08	3.37d±0.16	3.37b±0.22	0.98c±0.07	0.64b±0.02	05

Source: Idowu *et al*, 2003

LOCAL PISCIDAL PLANTS AND HARVESTING OF FISH

Since prehistoric times, cultures throughout the world have used piscicidal plants for fishing. *Hypoestes forskalei* (Roem Schult) of the family *Acanthececeae* is one of such plant with piscicidal properties which is being used by the local fish farmers in Cross River State of Nigeria to kill fish for human consumption. We mimicked this practice in the laboratory and observed that the fish exposed displayed irrational behaviour on the application of the plant (*Hypoestes forskalei*) extract to different developmental stages of *Clarias gariepinus*. These include vigorous movement, fast back stroke movement, restlessness, increased opercular movement and jumping (Ubaha *et al* 2012). These observations agree with the report of Agon et al. (2002) when they exposed the Nile tilapia (*Oreochromis niloticus*) to aqueous extract of dry tobacco dust (*Ncotiana tobaccum*). From the result of the study, it has been revealed that *Hypoestes forskalei* is a plant with piscicidal properties, highly toxic to aquatic lives especially fish and the water body due to its negative effects on the water parameters (temperature, pH, dissolved oxygen level) and hence can disrupt the balance of the ecological system since this toxic material can be transferred in the food chain (Table 39). On histo-pathology, the extract is shown to cause degeneration of the cells of the internal organs at different levels depending on the concentration (Ubaha *et al* 2012). Therefore, it is suggested that fishes

killed by the application of this extract to water body, should not be consumed due to the tendency that the extract may induce long term health hazards on the internal organs of the consumers.

Table 39: Duration of reaction and mortality of various developmental stages of the *Clarias gariepinus* fish

	Adult fishes		Juveniles		Fingerlings	
Concentration (Mg / l)	**Time recorded for 1st mortality (sec)**	**Duration for total mortality (min)**	**Time recorded for 1st mortality (sec)**	**Duration for total mortality (min)**	**Time recorded for 1st mortality (sec)**	**Duration for total mortality (min)**
0.0	0.0	0.0	0	0	0	0
500	18	76	15	23	12	20
250	26	60	25	35	24	29
125	40	90	32	44	25	35
62.5	90	90	31	60	24	42
31.25	0	0	40	90	40	90
15.62	0	0	70	180	110	2880
7.8	0	0	90	0	118	2880

Source:Ubah *et al* 2012

5.0 THE CURRENT STATE OF UNIVERSITY SCIENCE IN NIGERIA: THE REGROSSIVE DECLINE

As said earlier, I entered the university system in 1982 as a student and ever since I have remained within its boundary, but sadly I have witnessed so much of its decline and bastardisation that I am highly concerned of what will become of the system in some years to come. Equally worrisome is the state of our government owned primary and secondary schools, our feeder teams. Can we really move forward to achieving the desired 2020 or 2050 or 2100 goals as we keep hearing?

Sir, the likes of Prof F. M. A. Ukoli (of blessed memory) used to taunt me with a story of how the University of Ibadan used to compete favourably with Universities in Europe and America in terms of quality academics and laboratory equipments. So what happened? It is not so any more. A number of studies could not be concluded due to lack of equipments in the laboratory. The current state of the university system, especially the sciences is almost taking away the joy of being a lecturer. Our attitude and perception of science education in Nigeria both in the universities and at the primary and secondary levels raises serious concern. Kindly allow me to speak about my perceived challenges to scientific development in Nigeria.

INADEQUATE FACILITIES AND EQUIPMENTS

Mr Vice-chancellor, Prof. O.M Onagbesan will bear me witness that he as my first head of Department made life very difficult for me and my classmate then, why? Right from 100L we were made to pick a life rat, kill and dissect. If you made a mistake of making the animal "cry" (rupture one of the blood vessels), your punishment was to pick another and start the process all over. We did not pay any kobo apart from the initial tuition fees. I also remember that practical hand-out was free and our lecturer from all over southwest and Midwest were so committed to the point of volunteering to teach on Saturdays and Sundays, despite 14weeks of lectures. Sir, though tedious and strenuous, we the students saw it as opportunity to tap from the wealth of knowledge of these great teachers and we were there on time. But what is the attitude of students nowadays? May I also ask, what is the level of commitment of lecturers today? Those days, it was more of producing excellent students rather than just passing them through the mill.

Even at Postgraduate School, University of Ibadan, I had great access to facilities in the laboratories all alone. In some cases I had to do trial and error to familiraise myself with the equipments. Thank God for those technologists who were there to provide technical assistance. Materials were also available for collection from the store of the Department of Zool-

ogy store once one's supervisor and the Head of Department are convinced of their need. But what is the story today? Do our students have access to equipments? Is there adequate laboratory facilities available even for postgraduate students to step up their physiological studies without hindrances like I did when I was in UI? I could move within the campus anytime of the night to monitor my experiment. You are also sure that if there was a light out, you need not panic, stay where you were and in less than five minutes the light would be restored. But nowadays, light is a scarce commodity, our students cannot visit the store to collect materials for their researches, and the equipments available are not within their reach, and if they see them, they pay for their usage. Are we making progress or we are regressing? Also, despite the prescence of backbiting and politics in the Department, you were sure that at seminars, presentations whether pre or post data, will be at least, subjected to 75% academic rigour. The lecturers did not care less about your face or their popularity when they ask a candidate to go back to the laboratory or field for more work. But what do we have today?

Also, the facilities that housed 14 of us as undergraduate students is the same facilities that is housing 100-200 students today in most Nigerian universities. To make matters worse, two or three departments are competing with one another for the same facility. The implication of this is that practical classes

become very difficult to plan. In the sciences, practical exercises give life and energy to theory classes.

Unlike Nigeria, the grasshopper creates more room for additional structures as it moults to bigger sizes (Figure 3). The gland receives more attention in terms of tracheal supply, nerve endings and fat body attachment; creating room for efficiency. In Nigeria today, while our population is increasing the facilities available are declining especially in the academic sector. If education is the key to national growth and development then there is the need for a re-think of how government should fund education.

(Ps.a 11:3) If the foundations be destroyed, what can the righteous do?

Killing the initiative and dethroning the power of imagination

Mr Vice chancellor, recent experiences in our seminar rooms and from serving as external examiner for both undergraduate and postgraduate's programmes in other universities have convinced me that we are losing or totally abandoning the art of science gradually. It has become very difficult for our students to demonstrate some level of curiosity in their projects or research works. The route to a great discovery is seeing the little, the uncommon response or activity of the animal under

study, whether in the field or in the laboratory. Most students merely describe the results of their experiment from the perspective of the equipment leaving the real object, the animal-insect, goat or loin unattended to. We are interested in showing that we have arrived without the understanding of the basic rudiments.

How did we arrive at this juncture? The current state of the public primary and secondary schools that produced men and women in their 40s and above in Nigeria is a pointer to the declining state of Nigerian Science. What about the commitment of the teachers? Is there any fund for practical again? Do we still have regular practical classes in our secondary schools not to talk of primary schools? In my days at Okemesi Grammar School, current Ekiti State, we looked forward to the excitement of things happening in the laboratory- the colour change in the chemistry laboratory, or spirogyra under the microscope or the addition of iodine to starch and the resultant blue black colour made us shout 'wao'. This was the beginning of curiosity but unfortunately we are gradually destroying this developmental phase by our attitude to wish away practical classes because of greed and lack of vision for tomorrow by the government and the operators of the system. The best route to understanding science is in observing the phenomenon and developing the power of imagination in the young minds. How many of the undergraduates in this hall

had that experience, probably about 10%. Unfortunately, the private schools are making the matter worse by the unconventional way by which their students obtain high grades in their final examinations.

Recreating the passion for science in the heart of the young ones should be a matter of great concern. Raising creative pupils/students, with sound minds should be a major policy now if we will survive as a race in the coming millennium.

THE IDEA IS HERE BUT NO SUPPORT NIGERIAN SCIENCE AND RESEARCH FUNDS

One of the limiting factors to actualizing scientific dreams in Nigeria is the availability of funds for research. I have heard severally that there are research grants all over the world and that most of us are lazy in accessing them. Let me not talk about the politics of research grants and the interest of the developed world. I was so troubled that at one time I decided to take the matter up with one of my mentors, Prof O.O. Akinkugbe, an emeritus at the University of Ibadan, who then told me a story that I will like to share with you. He, as the Dean, College of Medicine, University of Ibadan was so concerned about the state of things in the college that he decided to seek for funds outside Nigeria to develop the college. He travelled to the USA and UK with the late Prof Akin Osuntokun who incidentally is from my hometown. As they moved

from one foundation to the other, the only response confronting them was do you not have the likes of Ford, Rockfeller and Co in your country? They came back and determined to seek the Rockfellers and the Fords in our country. Only one philanthropist responded out of the several that were written to. Our philanthropists, industries, companies, and individuals must rise up to the challenge of moving the Nigerian science forward by sponsoring research works and academic activities. The main point of this narrative is that what you need to develop your institutions should be within your reach. No father wants to develop and sponsor other people's children at the detriment of his own. The Nigerian government must set up grant facilities for studies on issues like malaria and typhoid fever, pests like *Zonocerus* and locust, Ebola and several others.

The solution to Nigeria problems lies in the hand of the Nigerian Scientists, who when funded will show genuine commitment and dedication to the challenges rather than the so called 'whites' who are more interested in neo-colonialism. To buttress my point, during the planning phase of the Aladja Steel Rolling Mill complex, the Nigerian government trusted the Russians bid as against the modest bid of the Nigerian scientists. We know what the result is today. We were told this story in 1983 when the Science Student Association of Ondo State University hosted the late Prof Ayodele Awojobi for a distinguished lecture. My prayer is that the Nigerian government

will take the issue of 'sponsoring' of research seriously and give it priority in the budget. The university system must also set up facilities to check the tendency to collect grant and not utilising it for the purpose it is meant for. Recently, we heard in the news of how European Universities organised a strong team made up of eminent professors to persuade the European Union not to cut their budget for research.

6.0. RECOMMENDATIONS TO GOVERNMENT

Given that science has been neglected over the years, there is the need for the government through the Ministry of Science and technology to set up mechanisms to re-awakening the growth and development of science in Nigeria. This, I hereby submit, can be achieved through:

(a) A review of extant policies on science education and scientific research for development of the human capacity.

(b) A policy by which Government recognises and engaged Nigerian scientists in the task of nation building in all its ramifications

(c) Providing adequate funding and infrastructures for effective engagement of the Nigerian scientists.

(d) Dedication of a special fund for the discovery and documentation of Nigerian Fauna.

(e) Specialised funding of key researches for mitigat-

ing the problems of malaria, sickle cell anaemia and diabetes through utilisation of indigenous plants for their treatment.

(f) Setting up a research and development fund to support effective research programme of Nigerian university

(g) Creating awareness for scientific awareness and creativity in our primary and secondary schools

(h) Sustenance of the Nigerian University Commission (NUC) university research fair for integrating the industry and the university.

(i) Promotion of publication of local journals with national and international appeal.

MY LAST LINE: I am hoping for a Nigerian Educational System where the following wiil be priority:

(1) the history and the culture of the Nigerian people are taught from primary to the University level. One of the lines in the national anthem says "the labour of our heroes past shall never be in vain", therefore, we need to educate the young generation of Nigerian about the contributions of the likes of; Sir Herbert Macualy, Dr. Nnamdi Azikwe, Cheif Obafemi Awolowo, Sir Ahmadu Bello and others to the Nigerian state.

(2) Nigerian plant and animal species are used as example

in Nigerian textbooks and teaching.

(3) The contributions of eminent Nigerian Professors/ Scientist are properly documented and introduce to young Nigerians as a way of motivating them to pursue careers in science.

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JEHOVAH YOU ARE SO GOOD TO ME

Grateful, so grateful for all that have done
I am so grateful for all you have done (2x)
Jehovah you have been so good to me
Your favour and your love lifted me on high
Jehovah you have been so good
And I cannot tell it all
With my whole heart, I give to you all praise
I give to you all praise
Oh Lord, I give you praise

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