UNIVERSITY OF PORT HARCOURT

STEALTHY THIEVES IN HOMES AND FOODSTORES

AN INAUGURAL LECTURE

BY

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INAUGURAL LECTURE SERIES

NO. 68

25TH FEBRUARY, 2010

DEDICATION

To

My wife - Joy Akate, and my sons - Ochure, Ejira, Ojuegbajima and Onenneh - for standing stoutly by me in all of life's challenges.

The Vice-Chancellor
Members of Governing Council
Deputy Vice Chancellor (Administration)
Deputy Vice Chancellor (Academic)
Registrar
Librarian
Provost of the College of Health Sciences
Dean of School of Graduate Studies
Deans of Faculties
Eminent Professors of the University of Port Harcourt and those of other Universities
My Lords, spiritual and temporal
Unique Students of the University of Port Harcourt
Gentle men of the Press
Distinguished Ladies and Gentlemen

1.0 PREAMBLE

I would like to begin this inaugural lecture with a personal anecdote. After my return in November 2003 from my 11–year academic sojourn in the ancient Borno city of Maiduguri, I continued from where I left off and commuted to my place of work from my ancestral home for another five years. With this, I fully qualified to be admitted as an important member of the **League of Rural Dwellers**. I became almost inseparably integrated into rural life – got involved in local politics, purchased all my family's daily needs in this big village, and participated in the social events that appealed to my fancy.

On one of these occasions, I went to buy a few drugs from a local chemist, and the lady proprietor, with probably less than the mandatory national basic education, confronted me and enquired to know if indeed I was a university professor. I answered to the affirmative, but it was obvious to me that she was not satisfied with my very modest answer. She then shared the source of her doubt with me. "I ask this rather embarrassing question because all the professors I'm familiar with are those that appear on TV who I see engaging in one national discourse or another. I have never sighted you on TV being addressed as one." I had to think out an appropriate answer at the speed of light – one that would suit her level of education and one that would grant me a quick exit from this embarrassing scene. I told her that the professors she sees and hears about on TV are city professors and I am a village professor – village professors don't appear on TV.

This quick answer got me out of further trouble. More important, from that day, I became a self-acclaimed village professor. And although I still don't appear or get heard of on TV, this particular event has given birth to the title of this inaugural lecture – *Stealthy Thieves in Homes and Foodstores*. Thieves in the rural areas are, in comparison to their city counterparts, more timid and "compassionate" to their victims – they would strike stealthily in the absence of the home or property owners. Thieves in the cities exhibit flagrant boldness and viciousness, maiming or even killing their victims before or after forcefully dispossessing them of their chattels and money. This is why the title chosen for my lecture won against several competing themes that could well have been quite apt for this inaugural lecture of the University of Port Harcourt.

2.0 INTRODUCTION

The Collins English Dictionary defines a thief as a person who steals something from another. Section 172(1) of the Nigerian Criminal Code as reported by Fakayode (1985) provides the legal definition of a thief thus, "*A person who fraudulently takes anything capable of being stolen, or fraudulently converts to his own use or to the use of any other person anything capable of being stolen, is said to steal that thing*." Criminal law recognizes robbery as a form of stealing and involves the stealing of property from a person by using or threatening to use force.

Although in all these definitions, thieves are perceived to be persons, not arthropods or insects to be specific, which form the object of my lecture, it is well-known that some species of insects are involved in kleptomania. These species, without man's consent, often deprive him of some of his very valuable possessions, and to this extent are regarded by entomologists as stealthy thieves (Ditcher, 1976). Do these organisms which were equally created by God to inhabit the earth, not have a right to live in any part of the earth, and exploit anything therein in the satisfaction of their own biological needs? Does man, who is supposed merely to live in competition with other earthly dwellers for the resources that God graciously put on the planet for the use of all creatures, have the right to label these creatures thieves? Or are these creatures taking more than their fair share of our earthly common wealth? These are the issues which this inaugural lecture is intended to address.

In the first place, man, the supreme creation of God, was empowered at creation, to dominate the earth and decide how all other creatures are to use any aspect of our so–called common wealth. In the story of creation recorded in Genesis 1:24–26, 28–30, man's right to adjudicate over the use of the earth's resources is clearly stated. "*And God said, let the earth bring forth every kind of animal, livestock, small animals, and wildlife." And it was. God made all sorts of wild animals, livestock, and small animals, each able to reproduce more of its own kind. And God saw that it was good. Then God said, 'Let us make people in our image, to be like ourselves. They will be masters over all life – the fish in the sea, the birds in the sky, and all the livestock, wild animals, and small animals. God blessed them and told them, 'Multiply and fill the earth and subdue it. Be masters over the fish and birds and all the animals. And God said, look! I have given you the seed bearing plants throughout the earth and all the fruit trees for your food.*

And I have given all the grasses and other green plants to the animals and birds for their food.' And so it was."

The second passage is in Psalm 8:6-8 "*You put us in charge of everything you made, giving us authority over all things – the sheep and cattle and all the wild animals, the birds in the sky, the fish in the sea, and everything that swims the ocean currents.*"

3.0 CLASSES OF PEST IN HOMES AND FOODSTORES

There are three main synanthropic organisms of relevance with regard to the domestic environment and these are rodents, fungi and arthropods.

Rats and mice, which prosecute their activities with some degree of violence, are the real robbers in homes and foodstores. They are the most important species of the order **Rodentia**. They are the most widespread domestic pests in the world (Agriculture Canada, 1979; Fenn and MacDonald, 1987). They cause serious problems in grain storage and processing premises although reliable figures relating to losses of stored products are extremely difficult to obtain (Odeyemi and Adedire, 2001). The greatest loss arising from rodent infestation is probably due to wastage and contamination of stored products with their hairs, droppings and urine which reduce the quality of stored grains.

Of the two groups of pest whose activities are surreptitious, fungal organisms form an important group, the other being arthropods especially insects and their discourse is the essence of this lecture. Fungi are probably second to the insects as agents of deterioration and loss in all kinds of stored products throughout the world particularly in the tropics where the physical factors of temperature and humidity, and poor product handling, favour their development (Jarvis *et al.,* 1983; Donli, 2001; Arinze, 2005).

Most of the storage fungi are moulds, and these invade agricultural products after harvesting and drying. There are, however, a few species such as *Aspergillus flavus* and related species which are now known to invade nuts and grains before harvest (Pitt and Hocking, 1999; Donli, 2001). Several species of mould are associated with grains especially cereals. Fungi growing on or in stored grains cause a variety of losses and these comprise reduced germinability, discoloration of parts or all of the seed, mustiness, various biochemical changes such as increase in fatty acids as well as production of mycotoxins; loss in weight, reduced market and nutritive value, etc.

4.0 ARTHROPOD PESTS OF STORED PRODUCTS

Vice-Chancellor Sir, because I am an agricultural entomologist, the main thrust of this lecture is on insects. Okiwelu (2005) in delivering the 39th Inaugural Lecture of this great University, took his audience on a guided tour of the fascinating and sometimes, bewildering world of insects. He did this job so well that it portends great wisdom to steer clear of this path that has been well worn by one of tropical Africa's entomological virtuosos. My chosen approach is to concentrate on those arthropods particularly insects which are associated with the domestic premises. This bias is quite understandable. Today's lecturer is an avid professional in the very exciting area of stored product entomology.

Lale (2002) in his classic book, *Stored Product Entomology and Acarology in Tropical Africa*, provided a useful summary of the arthropods found in the post-harvest environment. He reported that arthropods that play major roles either as pests or as natural enemies of pests are confined to the classes **Insecta** (insects) and **Arachnida** (the subclass Acari). The class Insecta is represented by members of the orders Coleoptera (beetles), Dictyoptera (cockroaches), Diptera (two-winged flies), Hymenoptera (e.g. wasps), Isoptera (termites), Lepidoptera (moths), Psocoptera (booklice) and Thysanura (silverfishes). The subclass **Acari** is represented by members of the mite orders Astigmata, Mesostigmata and Prostigmata.

While members of some of these arthropod orders cause detectable quantitative reductions in stored agricultural commodities, others are regarded as pests on account of their capacity to reduce the quality of these products through alteration of their chemical constituents or contamination with their excreta, cast old body parts, hairs and egg purses, and through tainting products with objectionable flavours and odours (Haines, 1991; Lale, 2002). Still others, especially members of the Hymenoptera and Prostigamata are parasitoids and/or predators of pest species and are thus useful as candidates for biological control of stored product pests in the tropics.

5.0 LOSSES CAUSED BY ARTHROPOD PESTS IN STORAGE

Varying estimates of losses caused by pests to stored commodities in the tropics abound in the literature (Lale and Ofuya, 2001). A number of studies conducted in the tropics consisting of spot checks of produce and carried out over a 30-year period arrived at losses ranging from 10 – 80% for cereals and over 50% for legumes (Anonymous, 1978). On the basis of subjective assessments and similar piecemeal observations, Appert (1987) reported that crop losses (from harvesting to consumption) were as much as 40% of production in the hot, humid regions of the world and more than 10% in the dry regions. These studies were not systematically carried out but were useful in bringing to the fore the enormity of the losses incurred in stored commodities in the tropics (De Lima, 1987).

Another series of projects which were more systematically and statistically planned and carried out between 1970 and 1985 by a number of International Agencies found that while heavy losses (over 50%) do occur in storage under conditions of poor management and technical know-how, the overall global estimate is about 10% for cereals and legumes. Estimates of post-harvest crop losses worldwide have been put at 10 – 20%, but 25 – 40% for the tropics by other workers (De Lima, 1987; Hill and Waller, 1990). Methodologies for evaluating on–farm storage losses are still evolving (Compton *et al.,* 1993).

Nevertheless, Lale and Ofuya (2001) and Lale (2002) have categorized losses attributable to arthropod pests in store according to the kind of damage and, in the case of crop products, also according to the part of grain or seed damaged. In crop products they comprise:

(1) **Loss in weight**: As insect and mite pests develop on stored commodities, they feed continuously and remove large amounts of the food materials – endosperm and cotyledons. This results in reduced weight of grains and edible seeds. Although estimates of actual loss vary considerably according to commodity, the pest in question, the locality and storage practices, losses of grains under traditional conditions in the tropics, on average, amount to 25% during a one-year storage period.

(2) **Loss in quality**: Infestation of grains and seeds by stored-product arthropods is often accompanied by detectable reductions in vital nutrients such as sugars, proteins, lipids, minerals, vitamins and other chemical constituents like alkaloids and caffeine. In some cases, the structure of these nutrients or important chemical constituents is altered irreversibly. The net effect of these is the lowering of both the food value of seeds as well as the industrial value of products such as palm kernels, cocoa, coffee beans and kolanuts. Lale and Okunade (2000), in a systematic study, showed that losses in caffeine content of up to 25 – 62.6% were incurred in kolanut infested by two species of kolanut weevils, *Balanogastris kolae* and *Sophnorhinus* sp. Lale and Igwebuike (2002) have also reported that the crude protein, ether extract and crude fibre of acacia (*Faidherbia albida*) pods, a popular animal feed in the savanna decreased with increasing infestation by three species of the Bruchidae – *Bruchidius atrolineatus, Acanthoscelides obtectus* and C*aryedon serratus*, and the Tenebrionidae, *Tribolium castaneum.*

(3) **Loss in Visual appeal/Market value:** Commodities attacked by arthropod pests are frequently contaminated with their dejecta and debris and have increased dust content. Grains infested by insects, for example, are riddled with holes and often accompanied by discoloration. Products prepared from such commodities may have an unpleasant taste/odour and/or unacceptable colour. This certainly reduces the visual appeal and also affects the market price of infested commodities especially those destined for export.

(4) **Indirect Loss by Microflora:** Under humid tropical conditions, initial damage of grains by arthropods promotes rapid growth of mould, and in the absence of adequate ventilation, may lead to caking of grains. This may spread rapidly causing severe indirect losses. The interaction between insects and fungi in enhancing losses in agricultural commodities is well documented (Pitt and Hocking, 1991, Donli, 2001).

(5) **Reduced Nutritional Value and Germinability:** The embryo of most seeds, especially grains is the most nutritious component. Its removal by storage pests inevitably tends to reduce the protein content of the seed or grain. The larvae of the lesser grain borer *Rhyzopertha dominica*, an important pest of cereals, for instance, prefers to devour the germ of pristine grains (Lale, 2002). Besides reducing its nutritive quality, damage to the embryo or its removal through pest depredation results in loss of viability. As early as 1971, Santos showed that losses in germinability of cowpea seeds infested by the bean weevil, *Callosobruchus maculatus* reached 100% for grains with 4 holes per seed.

6.0 PROBLEMS OF ASSESSING LOSSES

Recent reports on assessment of losses of stored products are scarce in the literature and some of those available provide outdated data on a few products. For instance, it was reported nearly three decades ago that about 4% of the total annual production of cowpea or about 30,000 tonnes valued at over 30 million US dollars is lost annually to the cowpea bruchid in Nigeria alone (Caswell, 1980; Singh *et al*., 1983). FAO (1989) also reported that 10% of the annual production of millet estimated at over 4 million US dollars was lost as a result of the activity of stored product pests.

Although it is widely recognized that losses of traditionally cured fish can be high, actual data on losses are very limited. One estimate is that about 3 million tonnes per year of dried fish is lost compared with an annual production of 12 million tonnes (US National Academy of Sciences, 1978). Losses are caused by microbial and insect attack, physical fragmentation and by chemical changes which alter the quality of products (FAO, 1981). Losses from beetle infestation have been put at 50% for the Lake Chad fishery (Rollings and Hayward, 1967).

The paucity of information on accurate and current losses due to storage pests is a direct consequence of the slow pace at which models for predicting losses are reported in the literature. The few models that exist so far were published by scientists from developed countries who conducted their studies in developing countries. Lale (2001) has given indication of the factors responsible for the apparent poor showing of indigenous scientists in this important area of entomological research.

1. Unlike their counterparts from developed countries, scientists in developing countries receive very little or no funding at all to conduct the large-scale and long-term research needed to generate data on losses of agricultural produce in storage.

2. Most entomologists have a strong aversion to ecological research because most aspects require mathematical (or quantitative) skills as in the case with development of models. For example, in the four volumes of the Nigerian Journal of Entomology for 2002, 2003, 2004 and 2005 which contained 57 articles, not one was in the area of loss assessment.

3. Nigerian storage entomologists, like their peers in many African and Asian countries, seem to have a strong preference for research bordering on the development of management tactics rather than the development of predictive models for assessing the economic importance of such pests. The large number of published articles on such topics as biotechnical research is an eloquent testimony to this fact.

Notwithstanding, ecological models are very valuable tools for the determination of the changing roles of insect species in a given environment. The larger grain borer, *Prostephanus truncatus* (Horn), for instance, was virtually unheard of nearly 30 years ago compared with its close relative, the lesser grain borer, *Rhyzopertha dominica* (F), a long established pest of cereal grains in store. Today, however, it ranks as one of the most destructive storage pests of stored maize that the world has ever known. Many storage pests, because they are *r*-strategists, have the capacity to attain pest status rapidly under certain circumstances. Because the damage and losses they cause cannot be accurately quantified and predicted over a period of time, man will always be faced with a “sudden emergence” of a new major pest with, perhaps, little or no preparation for its containment.

7.0 IN THE BEGINNING

The reality that untold losses of foodstuffs can occur suddenly, and thus threaten our food security situation gave birth to the practice of food storage in human history. And although the hunger crisis is most prevalent on the African continent, this situation is certainly one of the world's biggest ironies, because it is in Egypt, the centre of world civilization, where a government first promulgated the policy on the creation of a strategic stock to ensure food security for its citizens.

The nation of Egypt was threatened by a 7-year famine and its dire consequences but these were overcome as a result of the proposal by Joseph to establish a strategic stock. "*My suggestion is that you find the wisest man in Egypt and put him in charge of a national programme. Let Pharaoh appoint officials over the land, and let them collect one-fifth of all the crops during the seven good years. Have them gather all the food and grain of these good years into the royal storehouse, and store it away so there will be enough to eat when the seven years of famine come. Otherwise disaster will surely strike the land and all the people will die*" (Genesis 41:33-36).

And as Lale (2008) pointed out in his book, *Wisdom for Everyday Living*, the nation of Egypt did not only avert the disaster occasioned by famine in the whole world at the time, it made brisk business with the grains and other food items in the strategic stock as it sold foodstuffs to people of surrounding countries. United States of America learnt a good lesson from this, and being blessed with leaders with great foresight, it probably has the largest strategic stock not only of grains and other agricultural commodities, but also of crude and refined petroleum than many of the nations in the so-called Organization of Petroleum Exporting Countries.

How did Joseph's foresightedness impact on the economy of Egypt? "*And sure enough, for the next seven years there were bumper crops everywhere. During those years, Joseph took a* *portion of all the crops grown in Egypt and stored them for the government in nearby cities. After seven years, the granaries were filled to overflowing. There was so much grain, like sand on the seashore, that the people could not keep track of the amount. At last the seven years of plenty came to an end. Then the seven years of famine began, just as Joseph had predicted. There were crop famines in all the surrounding countries, too, but in Egypt there was plenty of grain in the storehouses. Throughout the land of Egypt people began to starve. They pleaded with Pharaoh for food, and he told them, "Go to Joseph and do whatever he tells you." So with severe famine everywhere in the land, Joseph opened up the storehouses and sold grain to the Egyptians. And people from surrounding lands also came to Egypt to buy grain from Joseph because the famine was severe throughout the world*" (Genesis 41:47-49, 53-57).

This indeed is food security *par excellence.* Food security is defined as "the deliberate policy to guarantee the citizenry freedom from hunger, malnutrition and deprivation through actions that ensure adequate and consistent food supply at affordable prices." The establishment of a country's strategic stock is the surest and most dependable way to achieve a nation's food security. As reported by Lale (2002), strategic stock is merely a stock of food grains and other agricultural commodities which serves as an insurance against famine which may arise as a result of bad harvests due to pest infestation or unusually bad weather, war or localized communal clashes accompanied by large–scale destructions. When any of these happens, these commodities are released systematically to meet urgent food needs. The strategic stock is often replenished regularly as the quantity of commodities diminishes.

Although food security has been the primary focus of many national governments since biblical times, its concept and practice are much better understood and established in the developed countries of the world than in the developing countries where its appreciation is relatively inchoate (Lale, 2001). Ivbijaro (1990) citing Nigeria as a typical case, enunciated some of the factors responsible for this situation─inconsistencies and frequent changes in government policy; inadequate infrastructure for the strategic stock; and inadequate price incentives for farmers and for those involved in the food storage business during the period of glut. Consequently, the storage of agricultural produce is, for the most part, in the hands of speculator-businessmen, with a small proportion being handled by farmers at the farm level.

8.0 OTHER REASONS FOR FOOD PRESERVATION

Besides providing for a country's strategic stock, Lale (2002) has given additional reasons why agricultural commodities are preserved in storage.

1. **Price Stabilization:** Agricultural commodities tend to be available in surplus during and immediately after the harvest and this forces price down, but become rather scarce as time progresses with attendant price increases. In order to regulate prices, agricultural commodities are stored so that they are affordable by the majority of people. It also ensures that farmers receive rewarding financial returns during the off-season for their effort and investment in farming.

2. **Provision of Raw Materials for Industry and International Trade:** Agricultural commodities serve as the raw materials for agro-based industries and as merchandize for international trade so that their continuous availability throughout the year guarantees the survival of those industries and trade. In Nigeria, for instance, virtually all the brewing industries at one time depended on the all-year-round availability of sorghum

grains for the production of different alcoholic and non-alcoholic beverages. Commodities such as palm kernels, cocoa and coffee beans, cassava products, kolanuts, ginger, to mention a few, are very important in international trade and importers expect that these should be made available in good condition on demand at any time of the year.

3. **Enhancement of a Nation's International Status:** It has become very common for nations to assist neighbouring nations in our global village facing natural or man-made disasters that threaten the citizens' access to adequate food supplies. Many countries but especially those in the developed parts of the globe (U.S.A., Canada, many European countries, Australia, etc) capitalize on these occasions to enhance their importance and to earn the goodwill of the affected countries. In Africa, Ethiopia and Eritrea, and other countries in the Horn of Africa, because of their geographical location, are especially prone to drought and this has caused untold suffering at various times in their history, and so they have been frequent beneficiaries of food aid in recent times.

4. **Provision of Seed:** Agricultural development in many tropical countries has not attained the level where seed for establishing new crops in each farming season could be obtained from seed companies. Consequently, every farmer must select from his harvest and store good grains that will constitute his seed in the following season.

9.0 TYPES OF STORED COMMODITY

There is an impressive array of plant and animal products that are preserved by man over differing periods of time. They include crop products, dried and smoked fish, meat, hides and skins and timber products. Besides these, there are household goods of various origin – clothes, carpets, books, etc. Traditionally, crop products are grouped into three classes – durables, semi-durables and perishables. A fourth class will comprise fish and animal products.

1. **Durables:** Durables comprise grains from both cereals (maize, rice, sorghurm, millet, etc) and pulses (cowpea, bean, groundnut, soyabean, etc) and other crops such as coffee beans, melon, dikanuts, ("ogbono"), palm kernel, nuts, etc; they can be preserved relatively easily for several months, and sometimes for a number of years. Their moisture content needs to be between 13% and 16%.

2. **Semi-durables:** These are the produce obtained from roots and tubers such as cassava, carrots, yams, cocoyams, sweet and Irish potato; they can be preserved for only a short time, usually underground or in barns.

3. **Perishables:** They comprise fruits and vegetables such as tomatoes, peppers, okra, oranges, pineapples, plantain/banana, onions, etc; they do not store well for any reasonable length of time and require some processing before they can be reasonably stored.

4. **Fish and Animal Products:** Although fish and animal products contribute immensely to human nutrition, they are nonetheless susceptible, when improperly cured, to maggots of blowflies especially of the family Calliphoridae (e.g. *Chrysomyia* and *Lucilia*), and when well cured, to skin beetles of the families Dermestidae and Cleridae, for instance, *Dermestes maculatus* Degeer and *Necrobia rufipes* (Degeer), respectively.

10.0 THE REAL STEALTHY THIEVES IN OUR HOMES AND FOODSTORES

The classical stealthy thieves which cause some of the most insidious damage that leads to economic losses in stored food commodities belong to the two holometabolous orders of insects – Coleoptera (beetles) and Lepidoptera (moths) both of which exhibit complete metamorphosis, that is development proceeds from egg – larva – pupa – adult (imago). A fundamental difference exists, however, between stored product beetles and moths. In most beetles with only a few exceptions (e.g. in bruchids where the adults do not feed), both adults and larvae, the only stages equipped with biting and chewing mouthparts, constitute the pest stages. In moths, it is only the larval stage which is so equipped that is capable of inflicting damage on crops or agricultural commodities in storage which constitutes the pest (Table 1).

For all of them, however, they are so small in size, and their activities are so often hidden that the damage they cause only becomes really apparent when the commodities have been almost completely devalued. This feature of stored product insects is what compelled Ditcher (1976) as Arinze (2005) reported, to make the following remarks: "If a farmer was told one-half or one-third of his grain had been stolen one night he would surely become angry and make a great effort to recover his stolen property and punish the thief, yet, each year many farmers lose 20-30% of their harvested grain, a little at a time, from the action of rats, birds, insects, molds and other causes. These stealthy thieves help to keep him in poverty and his family under-nourished."

Despite what orders or families they belong to, stored-product insect pests that attack grains and other plant seeds are divided into two different groups – primary and secondary pests.

1. Primary Pests: These are pests that are capable of penetrating and attacking the intact seed coat (and sometimes also a pod or sheath) of solid grains in order to feed on the embryos, endosperm or cotyledons of the seed and successfully completing their life cycles in them. Such pests also have the capability to feed on other solid but non-granular products such as dried cassava, but are unable to develop on milled or ground commodities (Haines, 1991). A few examples of such pests include the Angoumois grain moth, *Sitotroga cerealella,* the lesser grain borer, *Rhyzopertha dominica,* the maize and rice weevils, *Sitophilus* species and the cowpea bruchid, *Callosobruchus maculatus.*

Some primary pests, for instance, *S. cereallela, C. maculatus* and species of *Sitophilus,* commence their attack on mature crops in the field, and expand their population rapidly once the commodities are loaded in store where the conditions of humidity and temperature are more favourable. Primary pests such as these are called *field–to–store pests.* This is why field–to–store pests are better managed by including pre-harvest interventions while the crops are still in the field but just before harvest as Kabeh and Lale (2004) have shown.

2. Secondary Pests: These are pests that are incapable of attacking the hard undamaged seed coat. They attack and breed preferably in commodities that have been attacked initially by primary insects or previously damaged by some other agency such as bad threshing, drying, shelling, decortication, etc, or intentional processing of the commodity, for instance, milling of grains into flour. Some of these pests, for example, the merchant beetle, Oryzae*philus mercator,* and the rust–red flour beetle, *T. casteneum* are capable of attacking certain undamaged products, but develop rather slowly on them. They develop more rapidly on broken grains and seeds, grain dust and powder left behind by the primary pests. Other examples of secondary pests include the tropical warehouse or dried fruit moth, *Ephestia cautella* and the Indian meal moth, *Plodia interpunctella*.

As Haines (1991) has pointed out, it is necessary to emphasize that the word "primary" does not mean 'more important' but merely refers to the sequence of succession in the infestation of whole grains and similar products with a protective coat or surface. In some situations, secondary pests may cause more damage and lead to greater loss of stored products than primary pests.

11.0 STORING THE PRODUCE

Storage of agricultural produce is effected by means of structures differing in shape, capacity, construction materials, durability, cost and effectiveness (Lale, 2002). In the tropics, a large proportion of farmers' output is stored in simple and often precarious structures. In West Africa, for example, more than three quarters of the agricultural output is kept at the village level for use locally (Appert, 1987).

The structures generally possess many features that are fairly conducive to good preservation. They are constructed often with local materials and so are relatively inexpensive, their design and capacity differing according to the type of commodity and the size of the harvest. Seed-cotton, tobacco leaf, copra, and maize on the cob are all bulky crops and larger stores are required; even though some of these crops are only stored on-farm for a short period of time. Grains- shelled maize, pulses and the like are foodstuffs in a 'concentrated form' and only small stores are required.

For convenience, structures are categorized into two broad types- ventilated and unventilated (hermetic). A typical ventilated structure commonly used for the storage of durable crop products in tropical Africa is a small wickerwork hut with thatched roof and floor, raised off the ground to about 1m or less, and popularly known in Nigeria as a crib. The wickerwork walls generally allow free circulation of air and the thatched roof keeps off the rain. In regions with heavy rainfall, the roof eaves overhang considerably to prevent wetting of the walls. In some of the more protected stores the roof thatch is replaced with corrugated iron sheeting; the walls may be plastered with a mixture of mud and cow dung, and a well-fitting wooden door is provided.

In many tropical countries efforts are being made to improve traditional storage design. One idea is to fit rat-guards on the stilt legs of elevated stores. Another is to construct mud-brick storage containers which may be covered over with concrete and made airtight; produce inside is well protected and may also be easily fumigated. Unfortunately, many rural communities are reluctant to change their traditional patterns, so improvement has been generally slow.

Unventilated or hermetic structures are used for airtight storage. The philosophy behind airtight storage is the exclusion of oxygen from the structures so that pest insects and mites die from asphyxia. Unfortunately, natural enemies of pest species are also affected by reduced oxygen (hypoxia) or lack of oxygen (anoxia).

A good number of structures functions on this principle and are in use in the tropics. Airtight devices comprise simple plastic bags, jars, underground pits, earthen silos and metal bins.

12.0 GATHERING INTELLIGENCE

As Adedire (2008) pointed out in his 51st Inaugural Lecture of the Federal University of Technology, Akure, the contest between man and insect for access to the natural resources of the earth, is viewed in another context as a battle for survival. To succeed in any war, battles must be won, and to win any battle, gathering intelligence about the enemy forms a crucial first step. In military language, intelligence simply means information about enemies, spies, etc; it consists of information about their location, population size, the nature of the troops, their military prowess and so on.

To gather intelligence about pest arthropods, entomologists have devised various means of detecting and monitoring infestation in foodstores and warehouses. Lale (2002) has provided three key reasons why the detection of infestation is necessary.

1. Storage mites are not visible to the naked eye and the majority of storage insects are inconspicuous on account of their small size and habits. In addition, most species of stored products insect pests spend their pre-adult life entirely within the grain with no external sign of infestation. For the adults, some penetrate deeply into a commodity, whereas others, especially the larger species, are restricted to the surface.
2. If infestation is not detected, deterioration of stored commodities may occur abruptly, worsen rapidly and eventually lead to untold losses.
3. Early detection of infestation is also essential to ensure that measures for combating them are only put in place when necessary to reduce the cost of storage which is often transferred to the final consumer of the product so protected. This is equally important to forestall any possible non-target effects on natural enemies and consumers of protected products when measures comprise the use of insecticides.

Detection of infestation is therefore the process involving the careful inspection and observation of stored products for the presence of arthropod pests. To be of any practical value, it must be periodic and systematic.

While there are several methods for the detection of arthropod pest infestation which differ greatly in cost, effectiveness and complexity, there are usually three main approaches to accomplishing the process – direct examination of produce for the presence of pests especially for the adults which can be seen on the surface; trapping, based on the use of attractants especially pheromones (the most efficient chemical information technology developed by insects for communication between individuals of the same species); and technology for the detection of hidden forms of arthropods within stored produce.

Pest monitoring (or surveillance) on the other hand, is the periodic inspection and observation of the presence and changes in abundance of a pest occurring over time in a given commodity in storage. It enables entomologists or store managers to achieve four objectives: (i) to determine the proper time for efficient control of stored product pests; (ii) to minimize the number of applications of a pesticide; (iii) to estimate pest population levels; (iv) to identify problem species. Pheromone-baited traps are more efficient in achieving these objectives than light traps or traps incorporating different forms of chemical attractant.

There has been considerable progress in the use of pheromones for monitoring and control of stored product insects, since the pheromone of the black carpet beetle, *Attagenus unicolor* (= *megatoma*) was identified in 1967 (Silverstein *et al*., 1967). Pheromones from nearly all the species of major importance have been identified (Burkholder, 1982; 1984; Mbata *et al*., 1999). Recent advances especially in the chemical ecology of insects have enabled the elucidation of the structural identity of insect pheromones, and these have given impetus to the synthesis of analogues from different insect groups. Now, new traps are being developed and employed in the monitoring and management systems that utilize pheromones.

In many storage situations, the confined space and uniform habitat lend themselves favourably to insect management by pheromones (Burkholder and Ma, 1985). Determination of the presence of insects and their location within a warehouse or building can be accompanied by distributing pheromone-baited traps throughout the site. Suspected infestation may then be confirmed by inspection of the nearby commodities and storage area. It is equally important to determine the identity of infesting insects and to keep accurate records for future reference. Finally, control procedures may be modified once the species of insect and population densities are determined.

13.0 THE WEAPONS OF OUR WARFARE

Several strategies, differing in effectiveness, cost, complexity, method of application, side effects and persistence, are available to the entomologist for the management of arthropod pests of agricultural commodities. The overall success of any strategy is influenced considerably by economic and socio-cultural factors.

13.1 SOCIO-ECONOMIC CONSIDERATIONS

In typical subsistence agriculture, the prevention or reduction of physical losses of agricultural produce is aimed at making food available all–year–round to the farmer and his family. Any excess is then exchanged from time to time for his other requirements. Over the last few decades, the number of farmers who cultivate cereals and pulses purely for commercial purposes has increased appreciably so that the problem of grain storage has become more acute.

For these reasons, any method or strategy adopted for the storage and protection of agricultural commodities must, in addition to being effective, be economically justifiable and socially acceptable. This requires a proper understanding of the functioning of the post-harvest system in tropical Africa and this varies from country to country.

13.2 ECONOMIC JUSTIFICATION

Post-harvest treatment of any commodity is most likely to be undertaken by a farmer if he perceives that it will result in a tangible reward. For a subsistence farmer, this may be in the form of an extended period over which consumption of the commodity may be enjoyed. In a mixed subsistence and cash economy, or where crop is produced mainly as merchandise, farmers will make those changes in post-harvest procedures which they perceive will lead to increased revenue. This will be affected to a great extent by whether the initial cost-benefit ratio is positive. It is now an axiom that farmers will consider an initial cost-benefit of 1:2 as favourable.

As crucial as the initial cost-benefit ratio may seem, it is also important that an accurate analysis is carried out and presented in a form simple enough for the farmers to see the long-term benefits of any new post-harvest technology. For instance, the cost of metal silos for grain storage may appear prohibitive initially compared with the cost of a traditional crib of an equivalent capacity. However, metal silos are air-tight and may not require the use of insecticides or other protectants, and they are more durable in comparison with traditional storage structures. Making a success of such a proposition will require an aggressive extension service and practical field demonstrations.

13.3 EFFECTS OF SOCIO-CULTURAL CHANGES

In the last three decades, there has been a number of changes in the attitudes of consumers and this has had a significant bearing on pest control practices in tropical storage. Some of these changes include insistence on the purchase of commodities with higher standards of purity and aesthetic value, and which at the same time have minimal or no insecticidal residues at all. In addition, consumers also insist that food grains must be cheap.

This new level of sensitiveness to pest damage and the problem associated with it, has made the storage of agricultural commodities a very difficult business. To reduce the problems, an intensive educational programme through the extension agencies like the Agricultural Development Programmes in all the states of Nigeria, must be mounted to tilt the attitude of consumers in the right direction. Unless consumers are ready to accept a certain degree of pest damage to grains or other produce, then they should be ready to pay higher prices for these commodities.

In the present circumstance, farmers need to change from traditional storage methods to more effective but costlier methods of pest control. Farmers, however, tend to have great inertia in adopting technological innovations, more so if they will pay for such innovations. This problem can be minimized through purposeful extension services, practical demonstrations and increased institutional involvement in the storage of agricultural commodities in central silos. Institutional involvement will remove the burden of storage from the farmers who can now direct all their energies to crop production. For this to succeed, however, it may be necessary for governments to pay guaranteed prices for farmers' produce.

14.0 THE PART I HAVE PLAYED SO FAR

Vice-Chancellor, Sir, very distinguished ladies and gentlemen, permit me at this stage to focus my attention on the modest contributions I have made to the fast–evolving body of knowledge in the field of stored-product entomology. The result I am about to present range from data gathered from the research my colleagues and/or I conducted in the wetlands of the Niger Delta to those obtained from the drylands of the Savanna, and those from my work in Newcastle upon Tyne (England) and Goettingen (Germany). In carrying out this discourse, I shall endeavour to place my work in the milieu of the contributions of my predecessors, contemporaries and up and coming generations of entomologists in order to form the big picture. I shall accomplish this task under specific headings.

14.1 OBTAINING FIELD DATA ON FARMERS' PRACTICES, PEST DAMAGE AND LOSSES

Information on farmers' practices, pest damage and accompanying losses of commodities is essential to the design of appropriate technologies for effective post–harvest handling. My personal and collaborative research effort with some colleagues at the University of Maiduguri has yielded results that sufficiently justify the funds expended and the need for this line of work. In 1996/97, Lale and Okunade conducted a critical study of the practices undertaken by fish processors to preserve and protect their produce against pest infestation in the Lake Chad fishery.

Our finding that as high as 21.1% of the processors used organochlorine–based insecticide formulations for the protection of dried fish against blowfly larvae and skin beetles and the subsequent publicity given to this discovery in some of the national dailies have helped to check this dangerous practice considerably. Nevertheless, the development of safer and affordable alternatives remains an urgent issue because fish processors now know that smoking or sun-drying alone does not protect their fish against infestation by calliphorid maggots or skin beetles (Lale and Sastawa, 1996).

Kola is an important cash crop which is often plagued by field-to-store pest weevils that inflict serious damage on kolanuts and this results in economic losses annually. Kola weevils *Balanogastris kolae* (Desbr.) and *Sophrorhinus* spp. are reported to be the most destructive pests of kolanut in West Africa. To quantify both quantitative and qualitative losses associated with the activities of these weevils, a systematic 12-month (May 1995 to April 1996) survey that involved a monthly collection of kolanut from the kolanut distribution centre in

Maiduguri was undertaken. In separate reports, Okunade and Lale (1998) and Lale and Okunade (2000) reported a monetary loss of N46,229 per month, and this represented 34.8% of the total cost of a tonne of kolanut estimated at N132,836, and loss of caffeine that ranged from 18.8 to 62.6% in heavily infested nuts (nuts with 10 or more weevil emergence holes).

Pearl millet is a major staple food in the sudano-sahelian region of Nigeria, being second only to sorghum. Traditionally, farmers thresh their millet before it is stored, and threshed millet is more susceptible to damage by insect pests than unthreshed millet (Tannubil, 1991), and this results in losses estimated at over 4 million U.S dollars annually (FAO, 1989). It is well known that agricultural commodities stored in different structures or devices suffer varying levels of damage. To quantify the actual levels of damage to millet, Lale and Yusuf (2000) assessed the efficiency of the storage systems used for the preservation of pearl millet, the species of insect pests infesting pearl millet in storage and the extent of damage caused by insect pests between 1997 and 1998. Five species of insects – rust-red flour beetle (*Tribolium casteneum*), flat-grain beetle (*Cryptolestes ferrugineus*), booklice (*Liposcelis bostrychophilus*), lesser grain borer (*Rhyzopertha domimica*) and maize weevil (*Sitophilus zeamais*) – were found in the order of decreasing abundance, attacking pearl millet in storage. The preponderance of secondary pests over primary ones may be attributed to the poor threshing method that results in more breakage of grains. Secondary pests are known to thrive better than primary insects on broken grains (Heines, 1991; Throne, 1993). Without protection, pest damage tended to intensify with increasing storage duration (Table 2).

Table 2: Mean Percentage of Pearl Millet Grains damaged in different storage systems in Northeastern Nigeria

Storage system	Storage duration (years) Range	Mean	% grain damage
Polypropylene sack	2-3	2.26a	14.0a
Clay pot	2-3	2.55a	15.8a
Rumbu	2.-4	2.83c	39.2b
Underground pit	3-4	3.33d	80.1c

Figures followed by the same letters in a column are not significantly different (P>0.05) according to Duncan's multiple range test. Source: Lale and Yusuf (2000).

14.2 MANIPULATING THE PHYSICAL FACTORS FOR THE CONTROL OF STORAGE PESTS

The manipulation of the physical factors for the control of stored-product pests consists basically of modifying the environment in which insects or mites live so that it becomes deleterious for the survival of the target species (Lale, 2002). It involves techniques like the manipulation of density–independent factors such as temperature and humidity as well as density-dependent factors such as amount of available oxygen, carbon dioxide or carbon monoxide.

Insects and mites generally have narrow environmental limits within which they survive and breed successfully (Lale and Vidal, 2003a, b). Any technique which can alter either the temperature or the humidity, without any detectable adverse effect on the commodity will therefore provide adequate protection against pest depredation. As Lale *et al.* (1996) and Okiwelu *et al.* (1998) have reported, species of *Oryzaephilus* especially the merchant beetle, *O. mercator,* appear to be quite amenable to environmental manipulation on account of their limited range of temperature and humidity tolerance.

The second approach is the modification of the atmosphere around the arthropod pests. This involves the alteration of the proportions of oxygen, carbon dioxide, carbon monoxide and nitrogen (Ofuya and Reichmuth, 1993; Mbata *et al.,* 1996) such that only a very limited amount of oxygen becomes available to the arthropods for respiration. In some cases, oxygen may be excluded altogether. Arthropods in this artificial environment eventually die as a result of asphyxia (hypoxia or anoxia).

The basic physical techniques that are currently available in tropical Africa include hermetic (anaerobic) storage, application of mineral dusts and exposure to the high temperature that is naturally available in some parts of the year in the semi-arid savanna. The use of low temperatures generated artificially and the alteration of gases as physical techniques for managing stored-product pests is not feasible currently in tropical Africa because of the low level of technological development and the high cost of importing requisite equipment from industrialized countries. This is even more pertinent because the people engaged in the production and storage of agricultural commodities are subsistence farmers who are unable to afford even the basic facilities that are available for the preservation of their produce. The deployment of these technologies for stored products protection may be feasible only on community basis or in government strategic reserves.

Because my research in this area has focused on the use of hermetic storage and solar heat, further discussion on physical control is limited to these two techniques.

14.2.1 HERMETIC (ANAEROBIC) TECHNIQUE

The hermetic technique is a simple, flexible technology for grain storage that does not require the use of pesticides; it can be practised on almost any scale as long as the devices to be used can be made to be airtight. Sealed polythene bags can also be used for partial hermetic storage against arthropod pest infestation. Agboola (1992) has, however, reported that certain requirements must be fulfilled in order to achieve successful hermetic storage and include; (i) storing only dry grain; (ii) making sure that the containers or structures are really air-tight; (iii) filling the containers as completely as possible; and (iv) keeping the container at uniform, cool temperature.

In an experiment he conducted at the University of Port Harcourt, Lale (1993) evaluated four storage systems with varying levels of ventilation and reported that the degree of ventilation played a significant role in the effectiveness of the storage systems in checking infestation of cowpeas by the bruchid *Callosobruchus maculatus*. He reported further that the unventilated device was the most effective both in enhancing the efficacy of dry *Capsicum frutescens* powder used as a protectant and in the depression of egg-laying by female bruchids and impairment of the development of the insect to adulthood.

The anaerobic technique functions on the principle that as arthropods respire and use up oxygen that may be contained in the storage device, carbon dioxide builds up. Arthropods will, at first, die from reduced oxygen (hypoxia) and thereafter from lack of oxygen (anoxia). With increasing concentration of carbon dioxide, they eventually die from carbon dioxide poisoning, a condition known as hypercarbia.

14.2.2 USE OF HIGH TEMPERATURES

The utilization of heat for stored products protection is based on the knowledge that arthropod pests die when exposed to high temperatures because of their limited physiological capacity to thermoregulate, and because three target stages (eggs, larvae and pupae) live on or within grains and are thus immobile, are largely unable to escape from a hot environment (Murdock *et al.*, 1997).

This knowledge has led to extensive investigations in the laboratory (e.g. Iloba and Osuji, 1986; Murdock and Shade, 1991; Kitch *et al.*, 1992). In these experiments, exposure to temperatures between 50-60^{0}C killed larvae and pupae living within seeds and killed adults living among the seeds. Murdock and Shade (1991) further reported that these ranges of temperature had no adverse effect on the cooking time and germinability of cowpea seeds protected in this way. These results formed the foundation on which several field studies were based. The first of these was the work by Kitch *et al.* (1992) which was carried out in northern Cameroon and involved the deployment of fabricated solar dryers for protecting stored cowpeas. This procedure kept the produce clean and free of insect pests.

This result provided the impetus for the preliminary study of Lale (1998) which was conducted in the Nigerian savanna where there is abundant sunshine virtually throughout the year, but particularly during the hot season, in the months of March to May, when daytime temperatures in the open commonly reach 50 – 60^0C and relative humidities are as low as 10 – 20%. This is also the area where the bulk of the cowpeas consumed in Nigeria and beyond is produced. Unlike the work of Kitch *et al.* (1992), Lale's experimental protocol did not involve the fabrication of special solar dryers; it merely consisted of exposing cowpea seeds infested with bruchids in metal bins to solar heat in the open for a maximum of 3 hours. The results included depressed egg-laying, impaired egg viability and mortality of adults. In another piece of research, Lale and Ajayi (2001) showed that the capacity of solar heat to protect against infestation was still maintained even when infested produce was exposed to the sun in clay pots and polypropylene sacks.

On a fellowship provided by the Alexander von Humboldt Foundation, I was offered a place in the well-equipped laboratory of the Institute of Plant Diseases and Plant Protection of the University of Goettingen, Germany to carry out more detailed simulation studies between 1999 and 2000. As in the preliminary study, females of two species of the Bruchidae, *C. maculatus* and *Callosobruchus subinnotatus* (Pic) laid very few eggs, of which only a small percentage developed to adults, and larvae especially first instar larvae of both species died in bambara groundnut seeds (Lale and Vidal, 2000). The results also showed that immature stages of *C. subinnotatus* were more susceptible to heat treatment than those of *C. maculatus* (Lale and Vidal, 2003a). Exposure to high temperatures also led to the prolongation of development in both species (Lale and Vidal, 2003b).

Although the precise bioactivity of elevated temperatures on insects as other aspects of insect physiology and biochemistry is in a state of flux, it is known that changes in lipids, particularly increased fluidity of phospholipid membranes in the nervous system, metabolic rate imbalances, perturbation of ionic activities, as well as desiccation have been proposed as possible mechanisms of death (Fraenkel and Hopf, 1940; Cherry, 1959; Vardell and Tilton, 1980, Fields, 1992). High temperatures are also known to cause heat stupor (inability to move) and finally death in adult insects (Chapman, 1982). It has also been reported that insects die at low humidities from the effects of desiccation and in many cases low humidities make insects more susceptible to heat (Chapman, 1982; Fields, 1992). Death at high temperatures may result from various factors besides the fact that insects have a limited physiological capacity to regulate their body temperature. Proteins may be denatured (Chapman, 1982), and there is a positive correlation between the temperature at which pyruvate kinase, a key enzyme in glycolysis, is inactivated and the body temperature of insects (Hochachka and Somero, 1984). The balance of metabolic processes may be disturbed so that toxic products accumulate (Chapman, 1982).

Whereas it is possible to exploit high temperatures generated by the sun in the sudan and sahel savanna areas of Nigeria for stored products protection against arthropod pests, there is the need to fabricate solar dryers in the south where temperatures throughout the year are far below the levels investigated so far.

Success in this proposition will require a well orchestrated collaboration between entomologists and agricultural or mechanical engineers.

14.3 BIOTECHNICAL STRATEGIES FOR MANAGING STORAGE ARTHROPOD PESTS

The biotechnical approach to combating arthropod pest activities in the storage environment consists basically of three tactics – (1) use of resistant crop varieties, (2) use of genetically modified organisms (GMOs) and (3) the development, formulation and application of products of insecticidal plants.

GMOs are products of biotechnology – "any technique that uses living organisms, or substances from those organisms, to make or modify a product, to improve plants or animals, or to develop microorganisms for specific uses" (OTA, 1989). Even with allowance for the public concerns over biosafety, the production of transgenic crops via genetic engineering is a high-tech procedure. Success with this procedure has worked with a few food crops (e.g. maize, soybean, Irish potato, etc) especially in the more developed countries of the world. Because of the low level of our technological development, biotechnical procedure of this kind is not receiving as much attention as it should in tropical Africa where there is still a heavy reliance on methods of traditional, time-consuming mendelian procedures for breeding crops that are resistant to pest attack.

14.3.1 USE OF RESISTANT VARIETIES

The deployment of resistant varieties for the management of arthropod pests associated with stored crop produce is based on the knowledge that in nature, there are races within a wild crop progenitor that are capable of resisting pest depredation. These races are often selected by breeders and the genes conferring such potentialities on them are then carefully incorporated into a cultivated crop of the same species as a means of pest control.

The most intensive investigations into the understanding of the underlying mechanisms of resistance have been concentrated on cowpea which provides the cheapest dietary protein for people in tropical Africa. Present knowledge on the subject indicates that antibiotic chemical factors in the seed coat and in the cotyledons of resistant varieties of cowpea and other food legumes are responsible for the protection provided against pest attack. These factors cause deaths in eggs and/or larvae, lead to poor larval and adult development in bruchids attempting to infest resistant pulse varieties (Lale and Efeovbokhan, 1991; Lale and Kolo 1998; Lale and Makoshi, 2000).

In cereals, differences in varietal resistance are mainly a reflection of the differences in the physical factors of hardness, seed size and seed coat thickness. For instance, Lale and Kartay (2006) evaluated some local cultivars of maize for their resistance to the maize weevil *S. zeamais*, and found that one cultivar which had small seeds with thin testae and soft kernels was infested more than another cultivar composed of large seeds with thick testae and hard kernels. Similar conclusions were reached earlier by Lale and Modu (2003) and Lale and Yusuf (2001) in their experiments involving local cultivars of wheat and cultivars of pearl millet and the rust-red flour beetle *Tribolium castaneum.*

There are three fundamental dilemmas facing entomologists with regards to recommending the cultivation of resistant varieties of crops as a means of efficient crop storage: (1) The first is the fact that after a certain period of artificial selection, biotypes of the pest which are more capable of utilizing such varieties emerge through the process of Darwinian selection or mutation and the excitement of the earlier discovery and the huge investment in their development are lost; (2) Many resistant crop varieties leaving the breeders' garden have inferior agronomic characteristics leading to rejection by farmers; (3) Centuries ago, natural barriers such as mountains and huge water bodies between countries and even regions within a country served the useful purpose of prolonging the time span over which the dividends of a nation's investment in crop breeding can accrue. Today, the modern transportation networks have facilitated the movement of many pest species between different parts of the world. As a result, biotypes of pests that have the ability to successfully exploit the resistant cultivars of particular crops are more readily transported to regions having a population of strains of the same pest that lack this ability. Interbreeding between the two groups of the particular pest will lessen the control conferred by the resistant cultivar through genetic exchange.

14.3.2 INSECTICIDAL PLANTS

The tropical region of the world is endowed with a wealth of diverse floral species of medicinal and/or pesticidal value of which only a small proportion has been screened due to lack of appropriate technology and poor funding of needed research. In the last five decades, nonetheless, there has been a surge of interest in screening plant species for biological activity and I am happy to report that significant progress has already been made with promising results.

Products that are employed in stored products protection are obtained from different parts of the plant including leaves, roots, flowers, fruits, seeds, stem bark, exudates and so on. These are often formulated as solutions, powders and oils (Lale, 1995). Their bioactivity against pests comprises mortality of eggs, larvae and adults; inhibition or reduction of progeny development; sterility in adults; repellency in adults; reduction or inhibition of egg-laying. As Table 3 indicates, different plants possess different active ingredients from various chemical groups; while some have a broad spectrum of activity, others have a narrow range of activity.

Because many of the plants from which insecticidal products are obtained are edible, there is hardly any need to conduct toxicological studies to determine their biosafety to humans. But in the cases of non-edible products, the lack of toxicological data on possible side effects is a major restriction on their widespread use.

The major frustration being experienced by experts in this area of research is the near total lack of interest by local pesticide industries and other entrepreneurs to domesticate the exciting findings that have accumulated during this vigorous research epoch in the history of entomological development in Nigeria. If only they could partner with scientists in tertiary institutions along this line, the isolation, purification, evaluation and formulation of the cocktail of active ingredients in insecticidal plants represent one of the most appropriate and sustainable technologies that is well-suited to the current literacy level of our farmers. As Lale and Ajayi (1996) and Lale and Mustapha (1998) have shown, formulation expands the potentialities and efficacy of insecticidal plant oils in the protection of stored produce against insect depredation.

Will storage arthropod pests develop resistance to active ingredients of insecticidal plants as they have done to the major classes of modern-day synthetic insecticides? The development of resistance necessitates the use of larger amounts of protectants to achieve economic control; it increases the possibility of tainting stored produce which may be harmful to human health especially for those obtained from non-edible plants; it also increases the cost of storage, a cost component that is eventually transferred to the consumer. Giving an answer to this question is therefore critical to providing the impetus that investors need to lay out their capital for the extraction, formulation and marketing of botanical insecticides.

In their effort to answer this question, Sung *et al.* (2000) exposed adults of the saw-toothed beetle, *Oryzaephilus surinamensis* (L.) which was already resistant to chlorpyrifos–methyl to eucalyptus oil and 1, 8–cineole, a major component of eucalyptus oil. This resistant strain showed 1.9–fold and 2.2–fold higher tolerance against eucalyptus oil and 1, 8–cineole, respectively, relative to the susceptible strain. It is, however, quite heartening to state that no cases of evolution of resistant strains have so far been reported for insects that were not exposed previously to synthetic insecticides (Lale, 2002).

Another area of concern regarding the use of botanical insecticides is the inducement in some female insects of the phenomenon known as *hormoligosis*. In this phenomenon as Lale (1991) reported, sub-lethal doses of botanical insecticides stimulate female insects to lay more viable eggs and this leads to pest resurgence. Although Lale made this observation during his doctoral research, the phenomenon is now confirmed following detailed experiments by Ofuya and his team of researchers at the Federal University of Technology, Akure (T.I. Ofuya, Personal Communication).

14.4 INTEGRATED STORED PRODUCTS PROTECTION

Since the 1960s when the concept was first mooted, integrated pest management (IPM) has been evolving rather rapidly, and has come through a number of phases. Although it was born as a child of necessity to mitigate the environmental degradation and the threat to human health and safety occasioned by over–dependence on synthetic pesticides, one of its established roles is in recognition of the fact that, as it may have become obvious, no pest control tactic is fool-proof. Each of the pest management tactics presented so far in this lecture has certain inherent weaknesses thus making the development of any efficient integrated pest management system a mandatory responsibility for entomologists and other pest management experts such as plant pathologists, nematologists and weed scientists.

Although the concept of IPM has been in existence for at least 50 years, it has been evaluated mainly within the area of agricultural production in the field. To date, only few publications and working examples of IPM systems are available for stored products protection (SPP) even in developed countries. The situation is much worse in the developing countries but particularly in tropical Africa where the majority of plant protection scientists have strong traditional skills and much knowledge about single control methods and only few have been exposed to the contemporary knowledge of IPM. IPM, it has to be said, is a management system whose evolution correlates positively with advances in technology and the institution of good governance which places high premium on the development of the science and technology sector of its educational system, as reflected in the proportion of its annual budget devoted to research and development. The percentage of the annual budget for education in Nigeria ranks amongst the lowest in the world; development in all aspects of science and technology is at its lowest ebb. The real tragedy is that in the last two or three decades, funding in the educational sector has been experiencing rapid decline.

Vice-chancellor, Sir, very distinguished ladies and gentlemen, the few examples that follow are the attempts by my team of researchers and I to pick up the gauntlet and commence the process that we hope will snowball into the development of an efficient IPM system that is appropriate to our not-so-sophisticated farming system. The approach we adopted consists of the harmonious integration of two control tactics at a time and assessing the advantage of their synergy over each of the two tactics in combination. During this period we were able to evaluate; (1) Insecticidal plant oils (IPO) with host plant resistance; (2) IPO with hermetic storage; (3) IPO with solar heating, and (4) Hermetic storage with solar heating.

In these studies, the synergy created by the combination of any two management tactics provided the levels of control that were much higher than the sum of the controls that would have been possible should they have been applied individually (Lale and Mustapha, 2000; Ajayi and Lale, 2001a, b; Maina and Lale, 2004). For instance, the combination of varietal resistance and application of IPO for the control of the cowpea bruchid reduced susceptibility from the much higher range of 9.09 - 11.92 to the considerably lower range of 0.0 – 2.82 in cultivars of bambara groundnut (Maina and Lale, 2004); it reduced weight losses during a three-month storage from an average of 34% to 0.0 – 0.1% (Ajayi and Lale, 2001a). Similar results were obtained with combining varietal resistance in groundnut cultivar and IPO on the one hand, and combining varietal resistance with solar heating to protect against infestation by the groundnut bruchid, *Caryedon serratus* (Lale and Maina, 2002), on the other.

15.0 CONCLUDING REMARKS

From the foregoing, it is obvious that in certain situations man has been able to win some battles against insects, but he has not and will never be able to win the war against them. This ability of insects to continue to defy all of the arsenals developed and deployed against them by man stems from their pioneering existence on planet earth. Insects had been living on earth for at least 300 million years before the arrival of man (Fenemore, 1984). And as Adedire (2008) put it, insects have therefore thoroughly mastered the world and taken full possession of it, and have since been contesting every step of man's invasion of their original domain. He further stated that insects defiantly and flagrantly feed on our crops, suck out blood from the veins of our domesticated animals under our watchful eyes, and if they so desire, they may annoy us or even feed on our own blood or live with us whether we approve of this or not, and I dare add, steal our foodstuffs from us.

Vice-Chancellor, Sir, distinguished academics, ladies and gentlemen, as I try to close this lecture, permit me to state with a great sense of modesty that I have, along with my predecessors and contemporaries in the field, fought a good fight; I have run the race with uncommon endurance, and have been able to climb the last rung on the academic ladder. I wish I could add that I have also won the race. Nobody before me did and nobody after me will ever do. This is merely an admission of the fact that insects were endowed by our common Creator with the capacity to exhibit such resilience that enables them to defy man's advances in science and technology in the areas of space research, nuclear energy and genetic engineering.

What option then is left for man? The answer was provided by Adedire in the 51st Inaugural Lecture of the Federal University of Technology, Akure in 2008. "If man's continued existence on this planet earth is to be guaranteed, man has to change his tactics from absolute dominance to peaceful coexistence with insects; any attempt to exterminate them may result in an abrupt end to man's existence … "The age long struggle of who wins the conflict between man and insect should give way to peaceful coexistence between the two creatures of God." In the context of this lecture, man must accept that a certain degree of damage and the resulting loss of his agricultural produce in store is inevitable. He must be magnanimous enough to share these resources which constitute the common wealth of all creation with insects. After all, insects have shown incredible "kindness" by accommodating man in the home where they have been living for over 300 million years before man, like a stranger, arrived. To ensure that insects do not continue to take more than their fair share of these resources, he must continue to devise means and ways of keeping their populations at levels where they do not cause economic losses of our foodstuffs. This is the only practical way for man to ensure his own food security.

I would also like to exclaim like the apostle Paul did about the wonderful wisdom of God as contained in Romans 11:33, 36 "*Oh, what a wonderful God we have! How great are his riches and wisdom and knowledge! How impossible it is for us to understand his decisions and his methods. For everything comes from him; everything exists by his power and is intended* *for his glory. To him be glory evermore. Amen*." For if those before us had been able to exterminate insects from the earth, where would the Okiwelus, the Umeozors, the Lales, the Ofuyas, the Adedires, the Okwakpams and a lot of the other entomologists of our time be? But, because insects have continued to thrive in a world that can sometimes be unkind, we who could have probably lived and died in obscurity have made our modest contributions in man's attempt to live comfortably in perpetuity on the earth he shares with other inhabitants, even if these are lower creatures of God.

16.0 RECOMMENDATIONS

Given the enormity of the challenges posed by arthropod pests in the post-harvest environment of our agricultural system, and the desperate need to feed the bourgeoning population of people especially in sub-Saharan Africa, man needs to put in place an integrated assortment of efficient strategies for preserving his agricultural produce in the foodstore. It is in recognition of the importance of this that I make the following suggestions:

1. Because effective preservation of agricultural produce is a highly technical undertaking, it has become necessary for the three levels of government in Nigeria – the local, state and federal – to relieve the farmers of the burden of storage so that they can concentrate their efforts on crop, animal and fish production. In order to achieve this, the government should establish a system of buy-back devoid of political considerations in which the farmers are paid guaranteed prices. It should then establish large, well-fabricated silos where these stocks can be stored as part of the nation's strategic stock.
2. The government can and should also facilitate the process by which the farmers may constitute themselves into functional cooperative societies for the sole aim of prosecuting the storage of their farm produce on a group

basis. Non–governmental organizations can also assist in this effort. When this is achieved, Nigerian farmers would be protected against the usual slum in prices that is often experienced in the time of glut at harvests. This can become one veritable means of alleviating poverty amongst the farming population in the country. This is the kind of project that Nigerians expect NAPEP – National Poverty Eradication Programme to vigorously pursue.

3. There is also the need for institutional support. New biotypes of pest arthropods are constantly evolving, and to keep pace, better ways of checking their population must be developed, and reappraised regularly through research. The development and evaluation of new ways and methods of storage including the fabrication and assessment of new devices must be given priority in our tertiary institutions. In this regard, it is quite fitting to propose the establishment of an **Institute of Storage Technology** in the University of Port Harcourt to play a leading role in the nation's effort to attain food security in **President Umaru Musa Yar'Adua's 7 Point Agenda.** The technocrats to establish and operate the Institute should come from the Faculty of Agriculture and the **Department of Agricultural Engineering** which the Faculty of Engineering should endeavour to establish as a matter of urgency. Research support can also be provided by relevant departments in the Faculty of Science. In this regard, the departments that readily come to mind include those of Chemistry, Biochemistry, Animal and Environmental Biology, Plant Science and Biotechnology and Microbiology.

4. The last proposal, Vice–Chancellor, Sir, underlines the ever-present need for the link between university and industry. One of the most urgent areas that needs to be

addressed in order to fully exploit natural pesticides obtainable from locally available plants is formulation. The compounding of active ingredients into forms that can be utilized easily for pest control by farmers is a highly technical exercise requiring a deep knowledge of chemistry and related sciences. Nigeria has within its borders, a number of indigenous pesticide industries, for instance, Sygenta and Pam–Global Ltd, which should be able to pioneer the formulation of insecticides from plants for SPP. These industries should be made to collaborate with entomologists and other pest management professionals for regular bioassays of such formulations to confirm retention of bioactivity, their spectrum of activity and effects on non-target organisms especially for those that contain components that are non-edible.

TRIBUTES

Several persons have been involved in shaping my life and in providing various forms of assistance – funds, friendship, inspiration and motivation, enabling environment and encouragement – so that it is impossible to mention each one of them by name.

Nontheless, there can be no better way to start this section than by expressing my eternal gratitude to two of my maternal uncles – Messrs Isaac N. Chindo and Ebenezer E. Sakanwi, both of blessed memory – who made incomparable sacrifices and gave me the opportunity to extricate myself from the stifling poverty and deprivation into which my siblings and I were born. They did this by ensuring that I had education at least to the level of acquiring my Higher School Certificate. They did not, however, live long enough to witness how that initial effort of theirs had been transformed into a fulfilling career that has turned a village boy into someone that is now playing some significant roles on different platforms in big cities of the world either through his physical presence or through his writings. What a dream you had for me! Perhaps, without your vision and altruism, by now I would probably be digging foundation pits at construction sites to be able to fend for my wife and children.

My three siblings and I owe our Mom, a quintessential rural woman, profound gratitude for her sacrifice and for instilling in us the virtues of hard work and contentment. She had to be withdrawn from school after successfully completing class two and passing the prescribed examination to enable her to proceed to standard one, so that her Dad could marry her out as he did not want to see his first daughter "waste" her life acquiring western education. Some of her classmates who forged ahead and became teachers, clergymen and successful civil servants continue to give thanks to God for producing in me what my Mom might have been. She was not only brilliant, she came tops in every examination in classes where there were both girls and boys.

The wife of my youth, Joy, has remained my most dependable confidant, friend and support both in good times and in bad times. That is really what friends are for. I have always wondered what I would have been able to achieve or how I would have survived my many travails in life without her wise counsel, persistent prayers, love, motivation, understanding, care and the peace of my mind that she provides, emotional resources that every human needs to succeed in all endeavours of life. The arrival of our four boys has remained an added impetus, drive and inspiration to succeed and overcome even in circumstances that are extremely challenging and daunting. What on earth can be more frustrating and discouraging than a teaching job in educational institutions in Nigeria – whether these are primary, secondary or tertiary! I love you guys!

As Lale (2008) put it in his book *Wisdom for Everyday Living*, "Friendship is one of God's greatest gifts to man."

Several friends – both professional and social – many of whom are here today – have contributed in very significant ways to my success whether in just being there when I need them, or through their affirmation, inspiration, motivation or in sharing ideas and their resources with me. In this regard three of my professional colleagues – Professor T.I. Ofuya fesn, Professor C.O. Adedire fesn and Professor E. O. Ogunwolu – have been outstanding – they provided and continue to provide me with useful materials for research and publication, accommodation and meals on short notice and sometimes without notice when on my several journeys. In a world where selfishness, rivalry and wickedness are on the increase, their friendship has brought so much joy and encouragement that have enriched my life.

Many aspects of the arrangement for this lecture have been put together by some of my colleagues and friends in the Faculty of Agriculture who constituted themselves into an Inaugural Lecture Committee headed by Dr. A. A. Aiyeloja; Dr. E.S. Erondu painstakingly proof-read the manuscript of this lecture. I am indebted to you all.

Professor Samuel Nwabufo Okiwelu, fesn, occupies a special place in my life. His ardent belief in my capacity to make some contributions in the field of entomology and in national development since he "discovered" me in the early 1980s has remained a great source of inspiration. He was instrumental to my "first and second missionary journeys" to the University of Port Harcourt. Today, he quadruples as a professional colleague, a friend, a mentor and a father.

My second missionary journey which took effect from October, 2003 would not have been possible if it were not for the deep belief of Professor Nimi D. Briggs in meritocracy. As the Vice-Chancellor at that time, having been recommended by the then Dean of Science, Professor B.E. Okoli upon the consent of the Head of Animal and Environmental Biology, Professor Briggs approved that I rejoin Uniport to complete a career I began in 1982, and he did this against all odds. He went ahead and appointed my wife a Principal Nursing Officer at the Department of Health Services of the University. My entire family and I will remain ever grateful to you for these acts of altruism.

Having spent close to six years, I hope the quality of my contribution as an academic and my overall performance both within and without the university has provided a logical basis for breaking away from whatever stereotype that informed the misgiving that some expressed regarding my re-engagement.

Vice–Chancellor, Sir, I thank you most sincerely for appointing me into positions that have enabled me to express some of the natural endowments that would have remained latent otherwise, and for granting me the opportunity to present this inaugural lecture.

As we reminisce about all the experiences we have had since our return to our home University, my family and I have come to believe confidently that we will achieve all that God has destined for us. In ending this section of tributes, I am once again compelled to borrow from the apostle Paul who himself had to face more challenging situations in the course of his ministry as revealed in the Holy Writ in 2 Corinthians 3:4-5. "*We are confident of all this because of our great trust in God through Christ. It is not that we think we can do anything of lasting value by ourselves. Our only power and success come from God.*"

Thank you all for listening and God bless!

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CITATION

PROFESSOR NDOWA EKOATE SUNDAY LALE

Delivered by Professor (Mrs.) Bene Willie Abbey

Dean, School of Graduate Studies, University of Port Harcourt.

The Pro-Chancellor and Chairman of the Governing Council

Members of the Governing Council

The Vice-Chancellor

The Deputy Vice-Chancellors

The Principal Officers

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Deans of Faculties

Heads of Departments

Directors of Institutes, Units, Centres

Professors

Invited Guests

Staff and Students of the University,

Distinguished Ladies and Gentlemen

Professor Ndowa Ekoate Sunday LALE, the University's 68th Inaugural Lecturer was born to Philip LALE Efor and Evelyn Efor on 31 January, 1956 at Agbeta Ebubu, Eleme in Rivers State. His primary education began at Agbeta Eleme and in 1972 he was admitted into Ascension High School, Ogale Eleme where he obtained the West African School Certificate (Division One) in 1976. He went to Federal Government College, Port Harcourt for the Advanced Level GCE (Biology, Chemistry, Geography), which he obtained in 1978. During his GCE advanced Level Course, he developed an eye problem. This development was to influence his choice of University. He had heard of the famous eye clinic, Kano and decided to enrol in a University reasonably close to Kano, to ensure periodic check-up.

He was admitted into the University of Maiduguri in 1978 for a degree in Agriculture (Crop Science). This decision took the 22-year old, budding academic to a University approximately 1500km from home, away from his parents. The same stability, commitment and ambition that earned him Division One at Ascension High School, 3 Advanced Level GCE passes at Federal Government College, saw him through the University of Maiduguri, where he graduated with a FIRST CLASS B.Sc, (Honours) degree in Agriculture (Crop Science).

Professor LALE's NYSC service year was spent as a Lecturer in the Department of Agricultural Science, Advanced Teachers' College, Katsina Ala, Benue State. On completion of his NYSC assignment, he applied for a position in the defunct School of Biological Sciences, University of Port Harcourt in 1982. His interview performance was stellar and captivating, which led the three Professors on the panel, that included a Fulbright Scholar from the University of Detroit, USA, to exclaim in unison,

"**A FIRST CLASS MATERIAL ANYWHERE**"

On assumption of duty, young Ndowa Ekoate Sunday LALE did not disappoint his senior colleagues. He immersed himself in his duties with diligence. Starting a family was also in his mind. In 1983, he married former Miss Joy Akate Amadi, who is his wife, confidant, soul mate and mother of their FOUR SONS: OCHURE, EJIRA, OJU and NJIMAH. The following year, they travelled to The University, Newcastle-Upon-Tyne on staff development. He obtained the PhD in Agricultural Entomology in 1987. He was one of our staff development recipients who returned after completing their training. They were conscious of their indebtedness to the University and Country.

PROFESSOR LALE, I SALUTE YOU FOR YOUR PATRIOTISM!

On his return, his status was reviewed to Lecturer II and in 1991, was promoted to Lecturer I. During the turbulent period at the University of Port Harcourt, Professor LALE's spirit of adventure took him back to his *alma mater*, the University of Maiduguri where he was appointed Senior Lecturer in 1992. He rose to Readership in 1997 and was elevated to the rank of Professor of Entomology, Department of Crop Science in 2000. Aware of the incessant civil disturbances across the country, Professor LALE transferred his services back to the University of Port Harcourt, closer to his ancestral home, as Professor of Entomology, Department of Animal and Environmental Biology.

Professor LALE's research interests have focussed on the ecology, biology, control, with emphasis on the use of biopesticides in the integrated management of stored products pests. He has published over eighty scholarly articles in the Entomological Sciences in international journals worldwide. As at April 2009, scientists across the globe have accessed the website hosting his published articles more than 296,000 times, a resounding testimony to the impressive quality of his contributions to the field of entomology. He has served as External Examiner at undergraduate and graduate levels in Universities across the country. He has successfully supervised several M.Sc. and Ph.D. graduate students. In 1999, he received the Georg Forster Research Fellowship from the Alexander von Humboldt Foundation, tenable at the Georg August University, Goettingen, Germany. In 2007, he was honoured with a Fellowship of the Entomological Society of Nigeria for his immense contributions to the Entomological Sciences and the Society.

Professor LALE served as Coordinator of several programmes at the University of Maiduguri (1994-2002). He became pioneer Dean of the newly-established, Faculty of Agriculture, University of Port Harcourt in 2005. He is therefore a statutory member of the Appointments and Promotions, Capital Works and Development Committees. Since 2005, he has been Chairman, Board of Governors, University Demonstration Secondary School. His transparency, discipline, commitment and vision have transformed the school. In 2008, the Government of Rivers State, in recognition of his intellect and experience, appointed him a member, Governing Council, Rivers State University of Science and Technology, Port Harcourt.

In addition to the significant contributions in the Entomological Sciences, Professor LALE has ventured into other fields. His interest in stability at family and community levels, has prompted this motivational speaker, who possesses an enviable degree of integrity, deep appreciation of emotional intelligence, empathy and expertise in conflict resolution and management to produce two enthralling impact texts: BIBLICAL PRINCIPLES FOR SUCCESSFUL MARRIAGE and WISDOM FOR EVERYDAY LIVING. As a result of this development, there is a palpable anxiety in the Entomological Community that this high flyer may follow in the footsteps of the current Anglican Bishop of Egbu, Professor E. U. Iheagwam, one of the Country's foremost Entomologists.

Mr Chairman Sir, Principal Officers of the University, Professors, Staff and Students of the University, Invited Guests, Distinguished Ladies and Gentlemen, it is an honour and a privilege to introduce this Adventurer, Esteemed Entomologist, Alexander von Humboldt Foundation Fellow, Intellectual, Circumspect Academic, Seasoned Administrator, Motivational Speaker, Visionary and Crusader for Family Stability and Transparency in Leadership, to deliver the **68th Inaugural Lecture**.