OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, NIGERIA.

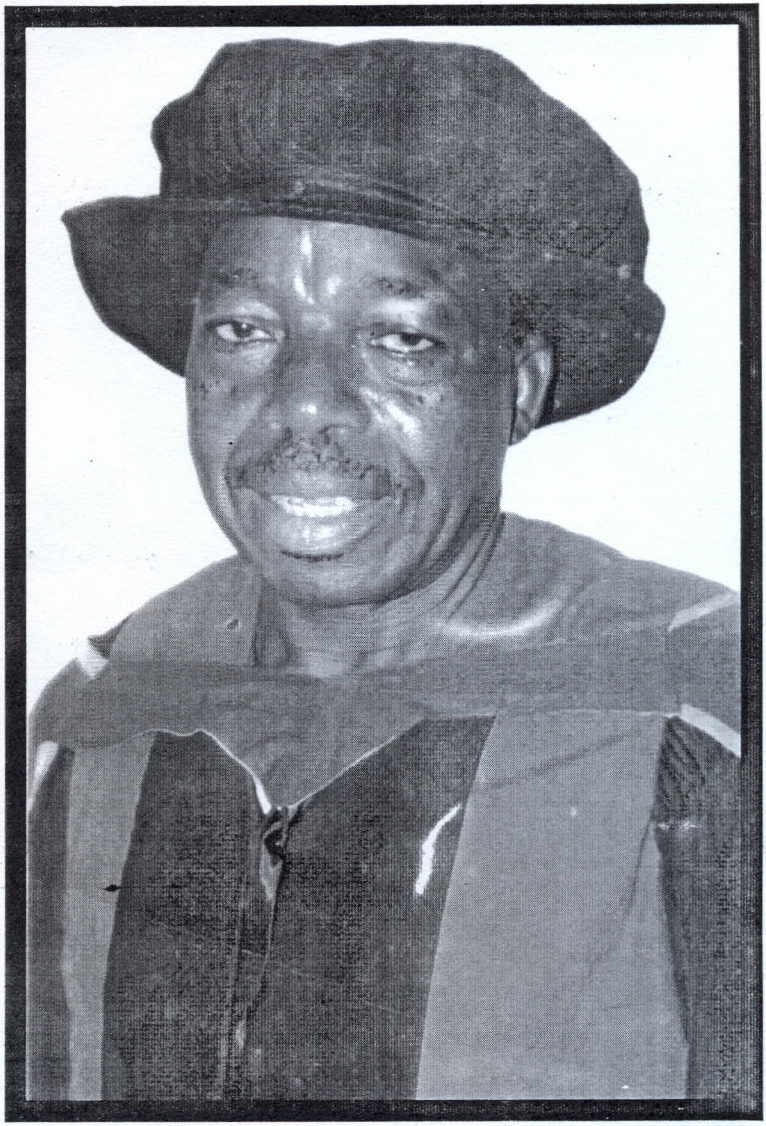
Inaugural Lecture Series 214

MICROBES: UNSEEN AGENTS OF ECONOMIC DEVELOPMENT

By

OLU ODEYEMI, OFR
Professor of Microbiology,

OBAFEMI AWOLOWO UNIVERSITY PRESS LIMITED.



Prof. Olu Odeyemi
Professor of Microbiology

MICROBES: UNSEEN AGENTS OF ECONOMIC DEVELOPMENT

By

OLU ODEYEMI, OFR
Professor of Microbiology,

An Inaugural Lecture Delivered at Oduduwa Hall, Obafemi Awolwo University, Ile-Ife, Nigeria, on Tuesday, 8th July, 2008

Inaugural Lecture Series 214

Obafemi Awolowo University Press Ltd., Ile-Ife, Nigeria.

ISSN 0189-7848

Printed by
Obafemi Awolowo University Press Limited
Ile-Ife, Nigeria.

Introduction

Microorganisms have been evolving nearly 4 billion years. For 2 billion years, microbes were the only form of life on earth. During this long history, all of the basic biochemistries of life evolved, and all life forms have developed from these microbial ancestors (Tiedje, 2008). This scientific theory of evolution is not in tandem with biblical theory of evolution recorded in the book of Genesis where microorganisms were not even mentioned. It is estimated that 50% of the living protoplasm on this planet is microbial. Microbes provide the fundamental underpinning of all ecosystems and without microorganisms, all life on Earth would cease.

Microbiology is the study of organism that can exist as single cells, contain a nucleic acid genome for at least some part of their life cycle, and are capable of replicating that genome. This broad description encompasses an understandably large group of organisms including fungi, algae, protozoa, actinomycetes, bdellovibrio, bacteria and viruses.

If you ask the average person how microbes impact their lives, they would immediately think of disease. This is understandable because of the morbidity and mortality caused by a number of disease causing microbes such as *Staphylococcus pneumoniae, Vibrio cholerae, Salmonella typhosa*, smallpox virus and influenza virus. For instance, in the fall of 1918, as the First World War was ending, an influenza pandemic of unprecedented virulence swept the globe, leaving some 40 million people dead in its wake. Smallpox was a feared disease throughout human history because it was highly contagious and mortality rates were as high as 40%. Those who did survive often had scarring due to blister-like pustules that form on the skin. The Yorubas almost deified smallpox calling it scary names such as "sanpona", "olodugbe", "oluaye", and "baba" etc. The current global HIV/AIDS pandemic also constitutes a genuine cause to dread microorganisms.

You may be surprised to learn that only a small fraction of microbes are involved in disease, most other microbes actually enhance our well-being and they are actually responsible for sustaining the planet Earth and especially the *Homo sapiens*.

This inaugural lecture is entitled "Microbes: Unseen agents of economic development" in order to focus our attention on the beneficial microorganisms and the economic power of microbes that have now transformed the small and virtually unseen bugs into big businesses.

The versatility of microbial biosynthesis is enormous. The most industrially important primary metabolites are the amino acids, nucleotides, vitamins, solvents, and organic acids. Millions of tons of amino acids are produced each year with a total multibillion dollar market. Many synthetic vitamin production processes are being replaced by microbial fermentations. In addition to the multiple reaction sequences of fermentations, microorganisms are extremely useful in carrying out biotransformation processes. These are becoming essential to the fine chemical industry in the production of single-isomer intermediates. Microbially produced secondary metabolites are extremely important to our health and nutrition. As a group, they have tremendous economic importance. The antibiotic market amount to almost 50 billion dollars and includes about 4,000 antibiotics and derivatives such as the beta-lactam peptide antibiotics, the macrolide polyketide erythromycin, tertacyclines, aminoglycosides and others. Other important pharmaceutical products produced by microorganisms are hypocholesterolemic agents, enzyme inhibitors, immunosuppresants and antitumor compounds, some having markets of over 2 billion dollars per year. Agriculturally important secondary metabolites include coccidiostats, animal growth promotants, antihelmintics and biopesticides. The modern biotechnology industry has made a major impact in the business world, biopharmaceuticals (recombinant protein drugs, vaccines and monoclonal antibodies) having a market of 15 billion dollars. Recombinant DNA technology has also produced a revolution in agriculture and has markedly increased markets for microbial enzymes. Molecular manipulations have been added to mutational techniques as means of increasing titers and yields of microbial processes and in the discovery of new drugs. Today, microbiology is a major participant in global industry. The best is yet to come as microbes move into the environment and energy sectors. Hence, microorganisms are significant gene pools and these gene pools must not be lost. Microorganisms can be regarded as a cultural heritage and a cultural property and they must be transferred to the next generation in a normal and healthy condition (Komagata, 1999).

The history of microbiology commenced in the latter part of the 17^{th} century with the work of Antony van Leeuwenhoek, an inquisitive Dutch merchant with no formal education. Leeuwenhoek ingeniously made himself several types of microscopes which were really magnifying glasses but which enabled him to observe the hitherto invisible microbes. However, it took about 200 years later in 1864 before Louis Pasteur conclusively proved the existence, origin and some functions of microorganisms. The work of Pasteur eventually became a major contribution to the birth of the science of Biochemistry and that of Microbiology. Therefore, the invisibility of microbes to the naked eye made their discovery and evolutionary process very slow. The word "microbes" was first introduced by S. Dillot in 1878 (Komagata, 1999).

Today, the various uses and importance of microorganisms are well known. All the world's civilizations have used products derived from microorganisms; and human beings have been making microorganisms work for them for a very long time even before the basic facts about microorganisms were known. For instance, the Egyptians five thousand years ago produced "leavened" bread and a kind of beer from fermented cereals. The Greeks and Romans produced wine and spread it across the world under their influence. The "leavened' bread, the beer and the wine must have tasted particularly good; and in a primitive way maybe the baker and the brewer saved a bit of that "special" dough or fermented material and added it to the next batch. This process went on down the centuries until "pure yeast" became commercially available in culture collections. They could be legitimately considered as the first curators (Zedan, 1998).

Similarly, Theophrastus, a Greek, about 2,300 years ago, noted that soil seemed to have more fertility after broad beans had grown in them and used the soil to fertilize other fields. It took another 2,200 years before the French Chemist, Pierre Berthelot, in 1885 suggested that some organisms in the soil might be able to convert or "fix" atmospheric nitrogen into a form that plants could use as fertilizer. A year later in 1886, the German Botanist, Hermann Hellriegel said that this fixing was carried out by bacteria that form nodules on the roots of the leguminous plant. In 1888, Dutch Microbiologist, Martinus Willem Beijerink witnessed the bacterium *Rhizobium leguminusarum* nodulating peas. Now and after 22 centuries, "nitrogen fixers" are available in culture collections as the basis of the biological nitrogen fixation industry.

Perhaps the most famous of all industrial fermentations is that of acetone-butanol production by *Clostridium acetobutylicum*. During the 1st World War, acetone, sorely needed for the manufacture of cordite (an explosive) was produced by this fermentation. Between the wars, the industrial use of microorganisms was extended, but it was not until the 2nd World War that the fermentation industries developed on the massive scale that we know today, the major stimulus being the need to produce antibiotics.

Modern biotechnology is enabling us to manipulate microorganisms such that we are eager to see products that kill pests, clean up oil spills and toxic chemicals, fertilize crops, improve human and animal health, etc. Twenty-six years after the United Nations Conference on the Human Environment in Stockholm, the world community is bracing up on the conservation of diversity in higher plants and vertebrates. However, equal attention is not given to microorganisms in spite of their importance and diversity, thus prompting the following questions (Zedan, 1998).

1. Why conservation of microbial diversity was not accorded similar attention as plants and animals despite the fact that microorganisms are by far simpler and less expensive to conserve than plants and animals?
2. Why conservation of microorganisms is not receiving necessary support from policy makers?
3. Why conservation of microorganisms was not the focus

of the debate on biodiversity conservation in different fora?

4. Is it because microorganisms are less familiar organisms?
5. Is it because the invisible is not close to the heart?
6. Is it because microorganisms are not charismatic creatures and are perceived by the public as killer agents?
7. Is it because little is known, if at all, about the contribution of microbial diversity and its contribution to national economies and human welfare?
8. Is it because of the failure of our national accounting system to reflect natural resources in national accounts?
9. Did national accounting systems fail because we do not have reliable techniques to quantify the economic value of microbial diversity or because there is not enough or organized information on such economic values?
10. Do we know with any precision the rate of erosion of microbial diversity and if it has slowed down or is increasing? Do we know the cost of inaction?

The Number of Species

There is a wide variation in the estimates of the number of species in the world. This is due to the lack of sufficiently reliable biological data and the fact that our knowledge of biology of most species is virtually non-existent and our knowledge of their functional importance remains fragmentary. This is compounded by the fact that increasing levels of complexity and new habitats are discovered progressively. We cannot measure satisfactorily the world's microbial diversity and our estimates of the loss of microbial biodiversity are therefore conjectural. Current estimates of the number of species of microorganisms compared with those maintained in service culture collections are given on Table 1 (Hawksworth, 1991). While just 40,000 algae species, for example, have been identified, more than 60,000 species are thought to exist. In the case of the fungal gene pool the number of species of fungi currently maintained in culture collections throughout the world represents 17% of the 69,000 accepted species of fungi, which itself is far short of the total number of fungal species that has long been quoted as 250,000, but is now conservatively estimated at 1.5 million. The same holds true for other groups (Zedan, 1998).

Table 1: ***<u>The numbers of species of microorganisms compared with those maintained in service culture collections (based on data compiled by D. L. Hawksworth)</u>***

Number of Species			Species in Culture Collection	
Microbial Group	Number Described	Estimation of Total Number	Number in Culture Collection	% of Total
Algae	40,000	60,000	1,600	2.5
Bacteria	3,000	30,000	2,300	7.0
Fungi	69,000	1,500,000	11,500	0.8
Viruses	5,000	130,000	2,200	2.0

Direct Economic Value of Microorganisms

Microorganisms are now playing significant roles in national economies. For instance, they are used for food production and preservation, production of antibiotics, making of oral contraceptives and other medicines, manufacture of vaccines, management of pests and pathogens, bioleaching of metals, enhancing soil fertility, generating biofuels, creating perfumes, monitoring pollutants, ridding coal mines from methane and acid drainage, cleaning up of oil spills, waste-water treatment, assaying of chemicals, compost fertilizer production, etc. Details of some of the above economic uses of microorganisms are described below.

Yeast Technology

Yeast manufacturing has steadily increased in tonnage, continuing its commanding lead over all other microbial propagations whose principal end products arc living cells. The versatility of this unique group of microorganisms is reflected in its ever broadening usage as the leavening and flavouring agent in breadmaking, as a nutritional enrichment in human and animal diets, and as a research tool in the basic studies of enzymology, nutrition and molecular biology.

Rich in nitrogen, vitamins and other growth stimulating compounds, yeast extracts are used as an ingredient in media for the cultivation of microorganisms. In fact, the story of bread, our most common food, is almost a summary of human civilization. Bread has made history and has unmade it, according to Jacob's (1944) fascinating and well-documented account in "Six Thousand Years of Bread". Single-cell protein production was first practiced in Germany during the First World War, as a result of shortage of food, using the brewers' yeast *Saccharomyces cerevisiae.*

Table 2: Yeast production in the U.S.A. (Peppler, 1967)

Type of Yeast	Quantity of Production (Tons/Year)
Baker's Yeast	56,000
Dried Yeast	
Food (*Saccharomyces cerevisiae*)	14,400
(*Candida utilis* – "torula")	1,600
Feed (*Saccharomyces* sp)	10,000
(*Candida utilis* – "torula")	2,800
Autolysates, Extracts, etc.	3,700

The production of this fungus on a large scale managed to replace up to 60% of the foodstuffs Germany had been importing before the War. The yeast after harvesting was incorporated into soups and sausage (Alofe, 1985).

Table 3: Estimated Annual World Yeast Production, 1977

Country	Bakers' Yeast	Dried Yeast (Tons)
North America	73,000	53,000
Europe	74,000	160,000
South America	2,700	2,000
The Orient	15,000	25,000
Africa	-	2,500
USSR	-	70,000

Tables 2 and 3 depict the production and consumption of yeast in the U.S.A. and the world, respectively. Single-cell (microbial) proteins such as *Candida utilis, Kluyveromyces f*ragilis and *Saccharomyces cerevisiae*, which contain more than 50% crude protein, have market value of over one dollar per kilogram (Table 4):

Table 4: Comparison of Selling Price Ranges for Selected Microbial Protein Products

Products, Susbtrate, and Quality	Crude Protein Content (%)	Price Range 1979 U.S.$/kg
Single-cell proteins:		
Candida utilis, ethanol, food grade	52	1.32-1.35
Kluyveromyces fragilis, cheese, whey, food grade	54	1.32
Saccharomyces cerevisiae: @		
Brewer's debittered, food grade	52	1.00-1.20
Feed grade	52	0.39-0.50

Source: *Office of Technology Assessment (1982): Genetic Technology – A New Frontier. Westview Press/Gromm Helm, Boulder, Co/London.*

The data are old but when we compute the 5-10% annual increase in yeast production from 1967 to 2008, it is obvious that the present global production and consumption of yeast are enormous.

Unfortunately, data are not readily available to assess the production figure in Nigeria. Nigerian well- trained microbiologists are encouraged to embark on commercial production of yeast and yeast extracts especially because of the huge market available in Nigeria and West Africa.

Suffice to say that on daily basis Nigerians consume relatively high amounts of yeasts through products such as bread and palmwine which contribute significantly to the economic development of the country.

Mushroom Production

Wild mushrooms were prized as a delicacy by the Pharaohs of Egypt and during the first century B.C., the epicures of the Roman empire held wild mushrooms in high esteem. Mushrooms were also eaten in ancient times in the Orient. Submerged culture production of mushroom mycelium for use as a food or in food products is relatively recent as compared with the older art of producing mushroom fruiting bodies or sporophores in manure or in compost beds.

Generally, one-third of mushroom grown in the U.S.A. (mainly the basidiomycete *Agaricus competris*) is sold fresh, and two-thirds is processed as canned whole mushrooms and soups, dehydrated soups, sauces, and frozen products such as precooked frozen meals.

Several mold species are the principal catalysts for imparting flavor to a wide variety of foods throughout the world. Such foods may be divided into two main categories, i.e. mold-ripened cheeses and fermented rice and soybean foods (Nelson and Richardson, 1967).

Edible wild mushrooms have been consumed by Nigerians for their nutritional, medicinal and condiment values since ancient times. The most commonly consumed species, especially in the Southwestern part of Nigeria belong to the genera *Lentinus, Pleurotus, Termitomyces* and *Volvariella* (Alofe et al., 2001 and Alofe et al., 1996). In spite of the importance of mushroom as a potential contributor to the economic development of Nigeria, the commercial propagation of mushroom is yet to attain any prominence in Nigeria.

Citric and Itaconic Acid Fermentations

Citric and Itaconic acids, both metabolic products of molds of the genus *Aspergillus,* are fairly strong organic acids. Citric acid is converted to itaconic acid by heating to 175°C.

Citric acid is the principal food acid used in the preparation of soft drinks, desserts, jams, jellies, candies, wines and frozen fruits. Citric acid is also used in gelatin food products and artificial flavors of dry compounded materials such as soft drink tablets and powders. In pharmacy, citrates are used in blood transfusion, and the free acid is used in effervescent products. Cosmetic uses of citric acid include those in astringent lotions where it is used to adjust pH and act as a sequestrant and in hair rinses and hair setting fluids. Citric acid is also used as a sequestering and complexing agents in electroplating, in leather tanning and in reactivation of old oil wells where the pores of the sand face have become clogged with iron (Lockwood and Schweiger, 1967). Itaconic acid's principal use is in the preparation of resin coatings for paper where an acrylic resin containing 5% itaconic acid offers superior properties in taking printing inks and in bonding.

It is obvious that these two fermentation products of *Aspergillus* are widely used in Nigeria but it is doubtful if they have ever been produced in the country.

Thus, citric acid and itaconic acid can serve as tools for economic development of Nigeria especially if they are produced locally.

Ethyl Alcohol Fermentation

Alcoholic fermentation is more generally known and more widely practised than any other microbial technology. It flourished for centuries before the role of living yeast was established by Pasteur, and pure culture principles were applied to improve the quality of the various end products. Ethyl alcohol, also known as ethanol, spirits, grain alcohol or methylcabinol, can be produced from a variety of sugar-containing materials by fermentation with yeasts. Alcohol-tolerant strains of Sacchromyces cerevisiae are usually selected. They convert only hexose sugars to ethanol and carbon dioxide, theoretically yielding 51 and 44% by weight, respectively, as expressed by the Gay-Lussac equation:

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$$

The resulting ethanol is then purified by distillation. There are three major uses for ethanol, viz (a) in the food industry (10%) as ingredient of alcoholic drinks, disinfectant and preserving agents (b) in the chemical-technical sector (21%) as solvent and as a building block for chemical synthesis and as fuel and fuel additive (69%).

In 2003, world ethanol production was estimated at approximately 40 billion litres, with Brazil and the USA being the largest producers (Berg, 2004). The raw feedstocks such as sugar cane and maize account for 70 to 80% of the overall costs of fuel ethanol. The recent upsurge in the use of these food crops for biofuel production to mitigate the effects of fossil fuels on climate change, has inadvertently given rise to sharp increases in food prices worldwide.

In 1983, my older brother, Prof. S.O. Odeyemi (former DVC, UNILAG) and I set up an ethanol production factory at Opebi area of Ikeja, Lagos. We made use of biogas digester to distil and purify locally made Igbokoda alcohol to produce alcoholic drinks and biofuel. Even though the project was truncated by the so-called "Nigerian factors", the idea later metamorphosed into the Intercontinental distillers, Ota.

As Nigeria is now embarking on bioethanol production through the NNPC, it should be mentioned that the future development cf the world fuel ethanol market is primarily a political decision, because the production costs for fuel ethanol are higher than for an equivalent amount of fossil fuels. World population will increase to 7.6 billion by 2020, as about 80 million people will be added each year, virtually all in developing countries. India, China, Pakistan, Nigeria, Bangladesh and Indonesia, will account fully for half of this population increase. This population growth is already stimulating substantial increases in demand for food and grain globally (Chrispeels and Sativa, 2003). Can Nigeria afford to divert its tubers and grains from the stomach of her ever-increasing peasant population for bioethanol production, even when the technology and cost of this biofuel production are not entirely within our reach?

Large volumes of beverage alcohol are produced and consumed in Nigeria. In particular, the brewery industry contributes substantially to the economic development of the country.

Microbial Production of Therapeutic Compounds

Since the introduction of penicillin as a therapeutic agent, there has been an ever-increasing contribution of fermentation technology to the production of therapeutic compounds. Hundreds of antibiotics useful in the treatment of infectious diseases, all of the vitamin B_{12} used in medicine and agriculture, and several of the medically important steroid hormones are now being produced on a large scale by microbial processes or by procedures involving microbial processes in the intermediate steps.

Antibiotics

World production of antibiotics exceeds 10,000 tons annually with an estimated market value of over 16 billion dollars in 1989 (Table 5). However, by 2008, the number of antibiotics has increased to about 4,000 with a market value of about 50 billion dollars. Nigeria consumes a relatively high volume of antibiotics every year due to the prevalence of various types of diseases. The use of vaccines, especially polio vaccines, in Nigeria is also substantial. The economic importance of these therapeutic agents is only or mainly reflected in their enhancement of good health of the citizenry as millions of lives of the people have been saved. Their economic values would have been more appreciated if most of the antibiotics are manufactured in Nigeria.

To illustrate the extraordinary diversity of microorganisms in terms of secondary metabolism, it is worthwhile to take a look at the secondary metabolites of the genus *Streptomyces* with approximately 140 species or groups. Approximately 3,500 antibiotic secondary metabolites have been recognized from the genus *Streptomyces* alone. Indeed *Streptomyces hygroscopius* alone produces over 180 secondary metabolites and *Streptomyces griseus* can be induced to produce more than 50 antibiotics in laboratory cultures. Given the endless combination of terrestrial, aquatic, and marine habitats and such enormous potential of secondary metabolite production in microorganisms and opportunities available for manipulation of the types and quantities produced in laboratory, the biotechnology industry has a tremendous resource at hand for the discovery of new chemicals for biotechnological application. It is therefore imperative that culture collections and information are globally co-ordinated and that habitats are protected not only because animal and plant species are being lost but also because unique microorganisms could disappear before knowing what was lost (Zedan, 1998).

Table 5: ***<u>World Antibiotics Market</u>***

Global Pharmaceutical Market (1989)	$150 billion
World Antibiotics Market (1989)	$16.1 billion
World Antibiotic Market (2008)	$50 billion
Percentage of Global Pharmaceutical Market	10.7%

Source: US Report on National Biotechnology Policy (1992)

<u>Industrial Enzymes</u>

The production of large amounts of penicillin which began in 1940 necessitated the development of new techniques of production of desired products or by-products under aseptic techniques. Such metabolites include penicillin, streptomycin, tetracycline, vitamins, aminoacids and enzymes. Industrial enzymes are obtainable from plants, animals and microorganisms. However, unlike plants and animals with limited capacities for enzyme production, the diversity of enzymes available from microorganisms is almost without limit. As at 1981, the global value of industrial enzymes was about two billion dollars (Table 6).

Table 6: *Typical Costs for Some Industrial and Speciality Enzymes*

Global Market Value of Industrial Enzymes (1981)	$900 – $2,000 million
Proteases	$3 - $10/kg
Carbohydrases	$10 - $30/kg
Lipases	$30 - $200/kg
*Speciality enzymes**	
Thermolysin	$100,000/kg
Alcohol dehydrogenyase	$100,000 - $300,000/kg

** These values have been estimated directly from 1988 catalogue prices (actually quoted on a "per mg" basis). These are highly purified enzymes designed for research use. For an economic large-scale application, prices might be as much as one-to-two orders of magnitude.*

***Source**: (Zedan, 1998).*

Biofertilizers

Africa used to account for more than 90% of the world's cowpea production and majority of the harvest used to come from Nigeria (Dobereiner and Campello, 1977). Groundnuts used to be an important export product especially in Kano State of Nigeria where heaps of groundnut sacks were popularly tagged "Kano Groundnut Pyramids". Vegetable oils and other industrial products from legumes were abundant and cheap. Unfortunately, Nigeria failed to exploit her vast legume potentials and consequently the "groundnut pyramids" of the early sixties are no more and the cost of groundnut oil has skyrocketed; and Nigeria now imports vegetable oils.

Since the cost of animal protein is almost beyond the reach of most poor Africans, an important contribution to solving protein crisis may lie in the exploitation of the Bradyrhizobium – legume symbiosis for mass production of food and forage legumes. For example, the use of highly infective, effective and promiscuous strains of Bradyrhizobium as inoculants for tropical grain legumes may increase substantially the grain yields of common crops like groundnut, cowpea, soybean, pigeon pea, faba bean and lima bean.

As can be seen on Table 7, 120 metric tons of nitrogen are fixed biologically every year with a market value of about 10 billion dollars as compared to only 60 metric tons that are fixed chemically via the Haber-Bosch Process. In 1975, the annual worldwide sale of Rhizobium inoculants was 20 million dollars.

Table 7: Biofertilizers: Global fixation of nitrogen and sale of Rhizobium inoculants (biofertilizers).

Process	Million Tones/Year	Cost
Globally fixed Nitrogen	200	
Chemically-fixed Nitrogen (1975)	60	$8–10 billion
Biologically-fixed Nitrogen	120	
Worldwide sales of *Rhizobium* inoculants (1975)		$20 million

***Source:** (Zedan, 1998).*

On the world scale and in terms of l.uman nutrition, legumes provide 22% of plants proteins, 32% of fats and oil, and 7% of carbohydrates; and in terms of livestock nutrition, they provide 38% of proteins, 16% of lipids, and 5% of carbohydrates (Wery and Grignac, 1983). Hence, massive use of Bradyrhizobia inoculants will enhance soil fertility, reduce import bills, ameliorate protein energy malnutrition and unshorten life expectancy in Africa. The so-called protein energy malnutrition has almost been completely wiped out in some developing countries such as Brazil, India, Indonesis and Mexico mainly as a result of massive application of rhizobia inoculant technology. For instance, the lack of protein malnourishment in Mexico is due to the traditional diet of dry beans and corn as the essential amino acids isoleucine and lysine are supplied by the beans (Dawson, 1970). Similar efforts could be made to eliminate protein energy malnutrition among the economically impoverished and nutritionally marginalized urban, shanty-town and rural slum dwellers in Africa.

Biopesticides

The microorganism Bacillus thuringiensis is a disease-causing bacterium whose spores are necessary for disease induction. These spores produce compounds that injure the gut of the insect larva in such a way that invasion of the body cavity follows. The organism produces four substances toxic to insects including a crystalline protein whose ingestion by caterpillars results in paralysis of their gut (Ware, 1978). The global sale of this biopesticide in 1987 was about 50 million dollars (Table 8).

Table 8: ***Global sale of biopesticides in 1987***

Global expenditure on crop-protectant chemicals (1985)	$15.9 billion
Bacillus thuringiensis global sales (1987)	$50 million

Source: *(Zedan, 1998).*

Food Industry : Porphyra (Nori)

Porphyra is an intertidal seaweed in the colder waters of the world. Nori or laver is vegetable made from dried Porphyra (Rhodophyceae) in Japan, similar to laver bread. The leafy thallus phase of Porphyra is eaten as a vegetable in Japan and Nova Scotia where the processed Porphyra is called Nori and laver, respectively. Porphyra was first cultivated in Tokyo Bay around 1700. The food value of Nori or laver lies in its high protein content (25-30% dry wt), vitamins, and mineral salts, especially iodine. The vitamin C content is about 1½ times that of oranges and it is also rich in vitamin B. Humans digest about 75% of the protein and carbohydrate, thus making it better than other seaweeds (Lee, 1980). The global Nori market was worth about 1.5 billion dollars in 1990 (Table 9).

Agar is another polysaccharide derived from red algae (Rhodophyceae). The pharmaceutical definition of agar is a phycocolloid of red algal origin that is insoluble in cold water but readily soluble in hot water, with 1.5% solution being clear and forming a solid and elastic gel on cooling to 32-39°C, not dissolving again at a temperature below 85°C.

The greatest use of agar is in association with food preparation and technology, and in the pharmaceutical industry. It is used for gelling and thickening purposes, particularly in the canning of fish and meat, reducing the undesirable effects of the can and providing some protection against shaking of the product in transit. It is also used in the manufacture of processed cheese, mayonnaise, puddings, creams, and jellies. Pharmaceutically agar is used as a laxative, but more frequently it serves as an inert carrier for drug products where slow release of the drug is required, as a stabilizer for emulsions, and as a constituent of cosmetic skin preparations, ointments, and lotions. The use of agar in bacteriology and mycology as a stiffening agent for growth media, for which purpose this material was used almost a century ago, is still responsible for a very considerable part of the demand (Lee, 1980).

Table 9: ***Food Industry : Global Nori market***

Nori (*Porphyra* red algae) World Market	$1.5 billion

Source: *(Zedan, 1998).*

INDIRECT ECONOMIC VALUE OF MICROORGANISMS

Microorganisms provide not only the basis for human life but also the basis for the life support systems of the biosphere. For instance, the vegetation of the earth's surface consumes about 90 billion kilograms of carbon dioxide per annum which is equivalent to $^1/_{25}$ of the total supply of the atmosphere. This means that the CO_2 of the air can be exhausted in 25 years if not replenished by microbial respiration (Alexander, 1991; Ogunseitan, 2005). That is, if the CO_2 locked up in plants and animals via photosynthetic activities are not released by microbial degradation of dead plants and animals, life as we know it now may cease to exist (Fig. 1).

Similarly, microorganisms are responsible for controlling the gases mix and quality of the atmosphere, amelioration of climate, regulation of Earth's hydrological cycle, generating and maintaining soils, disposal of wastes, recycling of nutrients, controlling of pests and running biogeochemical cycles.

THE CARBON CYCLE

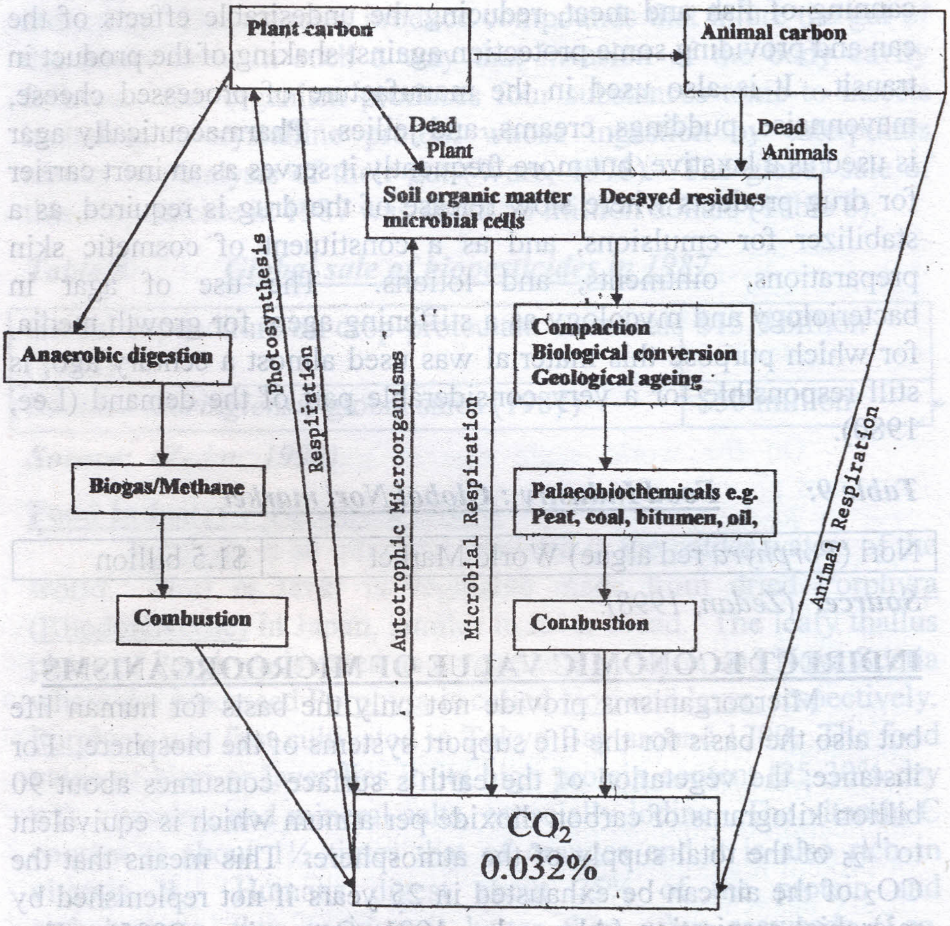


Fig. 1: The Carbon cycle

SOME OF OUR CONTRIBUTIONS TO THE USE OF MICROORGANISMS FOR ECONOMIC DEVELOPMENT OF NIGERIA

Biogas Technology

We were the first scientists in Nigeria to device a laboratory technique of measuring the relative volumes of biogas (methane) produced by various organic wastes such as animal dung, household wastes, municipal garbage, agricultural residues and weeds, when they are subjected to anaerobic bacterial digestion. Subsequently, we constructed and used the first biogas generator in Nigeria. Biogas is methane gas formed from organic wastes by bacteria and it can be used for cooking, heating and electricity generation. We have built four types of biogas plants for laboratory use, family use, village community use and commercial use, respectively. We employ this biogas for cooking and lighting at home.

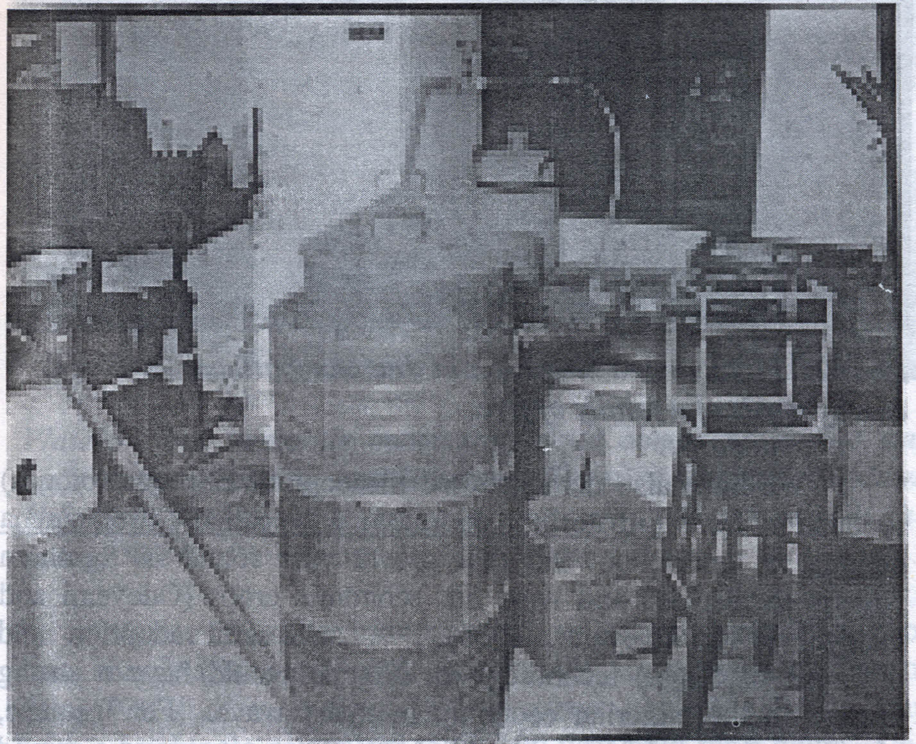


Plate 1: The first biogas plant constructed in Nigeria in 1982. It was used for cooking, heating and ensuring sterilization and aseptic techniques in laboratory bacteriology.

Plate 2: Family-sized biogas plant that can generate the biogas energy needs of a family of five.

We have also demonstrated the copious Eupagas (biogas) production from Eupatorium odoratum now called Chromolaena odorata, a notorious weed that grows year round in Southern Nigeria to displace and wipe out economic crops (Odeyemi and Olaoye, 1984; Odeyemi, 2005). A successful adoption and diffusion of biogas technology in Nigeria would have a strong impact on the Nigerian economy in many ways. For instance, biogas can be used for cooking, lighting, electricity generation and crop processing to reduce post-harvest losses.

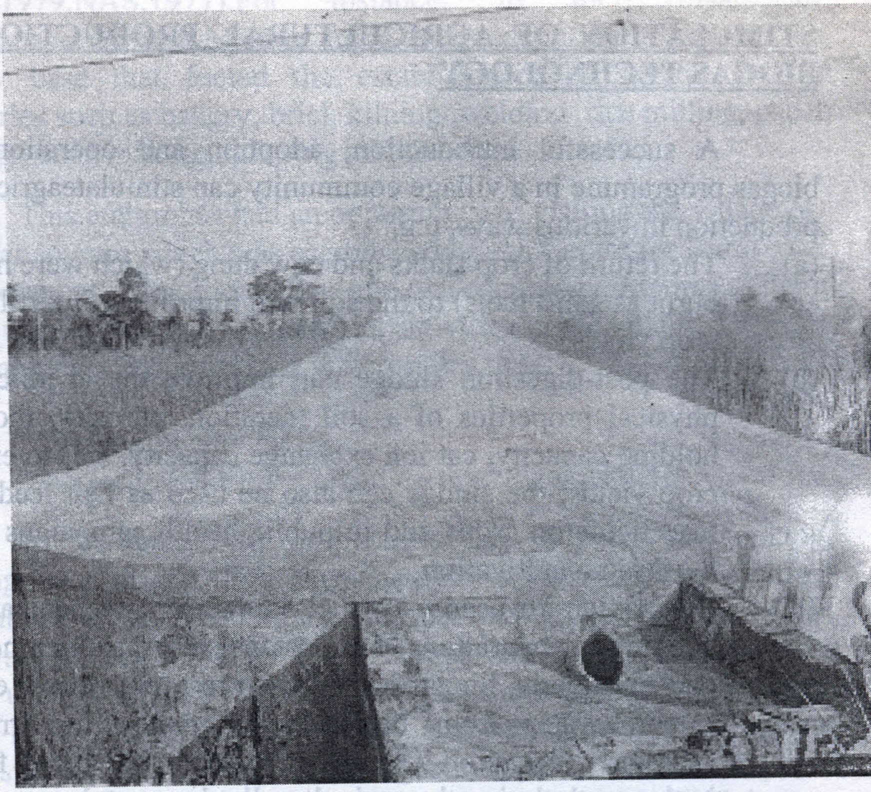


***Plate 3:* An immobile community-sized biogas plant that was built at the Teaching and Research Farm of Obafemi Awolowo University for cooking and crop processing. It can provide the energy needs of a community of 1,000 people.**

One cubic meter of biogas will generate about 6,000 Kcal of heat energy which can cook three meals for a family of five, or bring 130kg of water from 20°C to a boil, or light a biogas lamp with a brightness equivalent to 60-100 watt bulb for 6 hours. One cubic meter of biogas can also generate 1.25kwh of electricity (Odeyemi, 2005).

STIMULATION OF AGRICULTURAL PRODUCTION BY BIOGAS TECHNOLOGY

A successful introduction, adoption and operation of a biogas programme in a village community can stimulateagricultural production in various ways, e.g.

(a) The return of crop stalks and cow dung (which were hitherto burnt as solid fuels) to the soil will improve soil fertility and crop yields.

(b) The post-digestion sludge can improve the chemical and physical properties of a soil (aeration, porosity, moisture-holding capacity, cat ion exchange capacity, etc) to enhance crop yields; the sludge can also be used as fish feed, as an insecticide on crops and in public health campaigns and in mushroom cultivation.

(c) Biogas can be used as a fuel source for mechanization of agricultural operations .For instance, in the drier northern part of Nigeria, biogas can be used to power diesel engines to lift water from boreholes or ponds for irrigation .Similarly, irrigation water can be made available to farmers in the south during the agriculturally dormant dry season.

(d) Of utmost importance is the possible use of biogas for crop processing such as drying, rice milling and cassava grating as a means of preservation to minimize the usually huge post –harvest losses suffered by farmers in West Africa.

(e) Biogas as a source of heat can be used (in the absence of electricity to refrigerate and freeze plant and animal products that require preservation (House, 1981).

Thus, the on the farm processing of animal and crop harvests with digester gas will lead to spawning of cottage industries which can auto catalyze rural development .self-sufficiency, social stability and improved quality of life. China and Indian are good examples of developing countries that have used biogas to fuel successful rural development

(CSC,1979,NAS,1977).For instance, in the village of Narayanapuram near Madras, India, a cow dung-fed biogas was the energy base that fueled the establishment of several cottage industries such as bakery, brick kilning ,welding ,rice milling, paper milling , soap making, dairying and fishery .

This author has had an opportunity of visiting the village of Narayanapuram which was established by the Centre for Rural Development of the Indian Institute of Technology, Madras. After a trip round the beehive of industrial activities in the village, I remembered a Bible passage which states thus.

"I grant you cow dung.
You are to bake your bread on that" Ezekiel 4:15

Hence apart from the potential use of biogas for cooking, heating, crop drying, lighting, electricity generation, refrigeration, agricultural mechanization and crop processing the adoption of this renewable energy will save the labour and money that are now being used to procure firewood, and free the womenfolk from some of the heavy chores and housework. The sanitizing and hygienizing effects of the anaerobic bacterial digestion system will also improve the health of the rural dwellers to reduce their currently high rates of morbidity and mortality thereby unshortening their life expectancy (Odeyemi, 2005). Thus biogas has the potential for fueling economic, technological and social development of rural Nigerians to improve their quality of life. The use of biogas instead of fuel wood would also have an ameliorative effect on the currently alarming problem of deforestation to enhance the process of desahelization and desaharization of the West African sub region (Odeyemi, 2007).

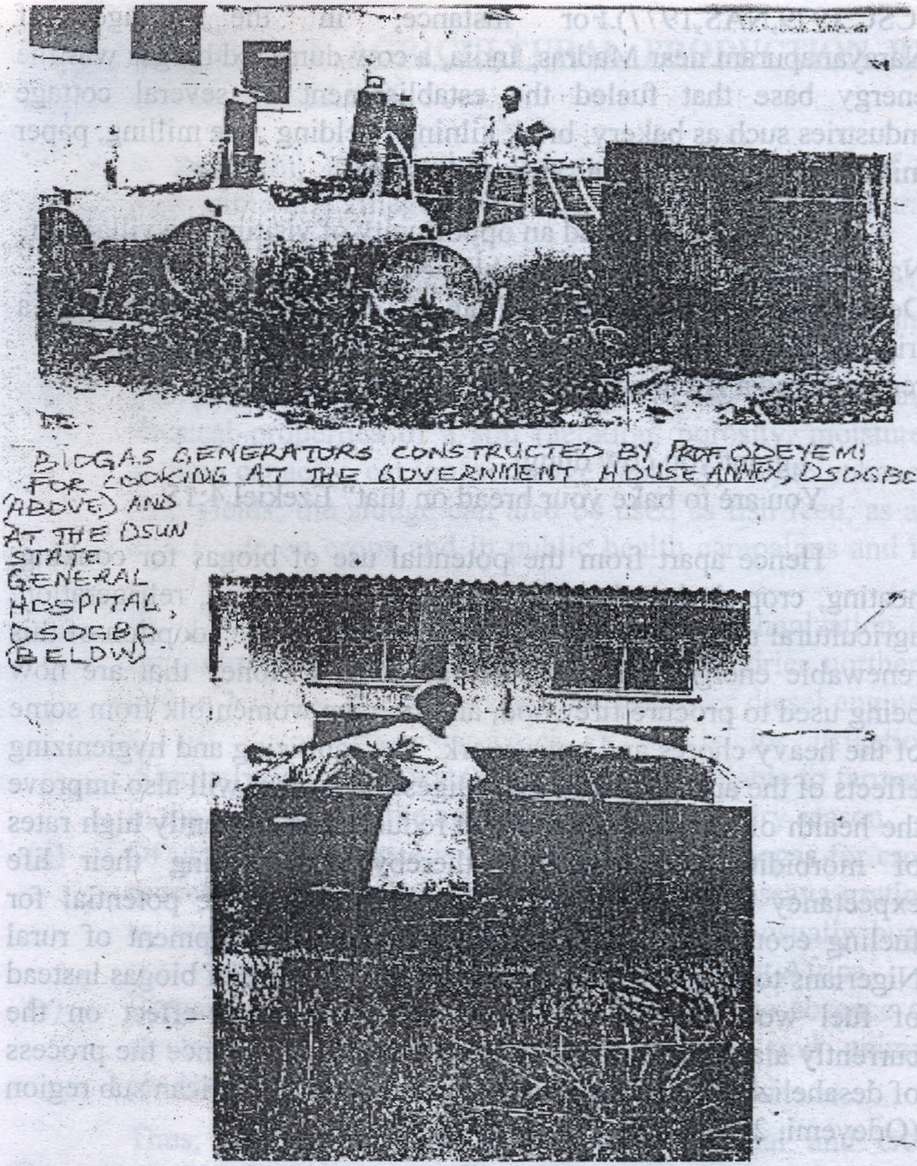


Plate 4: *Biogas Generators constructed by Professor Odeyemi for cooking at The Government House Annex, Osogbo and at the Osun State General Hospital, Osogbo.*

China and India are examples of countries that have used biogas to successfully fuel rural development. Nigeria also needs to adopt this technology for rural development.

Rhizobium Inoculant (Biofertilizer) Production

We were the first scientists in Nigeria or West Africa to screen and select elite strains of Bradyrhizobium (Nitrogen fixing and protein forming bacteria in legume plants) which are infective, promiscuous and symbiotically effective and therefore ideal for use as legume inoculants. This feat was achieved after 14 years of painstaking laboratory, greenhouse and field plot investigations (Oloke and Odeyemi, 1988; Odeyemi, 1991).

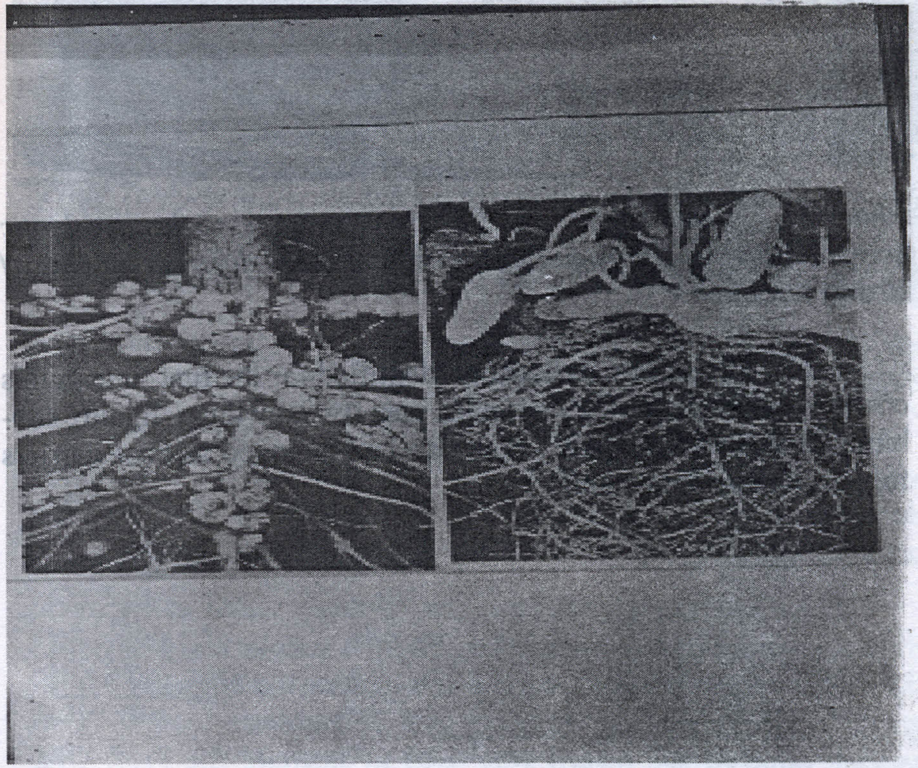


***Plate 5**: Root nodules of soybean and groundnut that harbour Rhizobium bacteria for symbiotic nitrogen fixation and protein production.*

Plate 6: *Greenhouse investigation to assess the symbiotic compatibility and nitrogen fixing potential of different strains of Bradyrhizobium*

We have also successfully identified for the first time in this country, suitable organic materials, namely: cow dung, lignite, sub-bituminous coal and peat which can be employed as base carriers for the rhizobia inoculants.

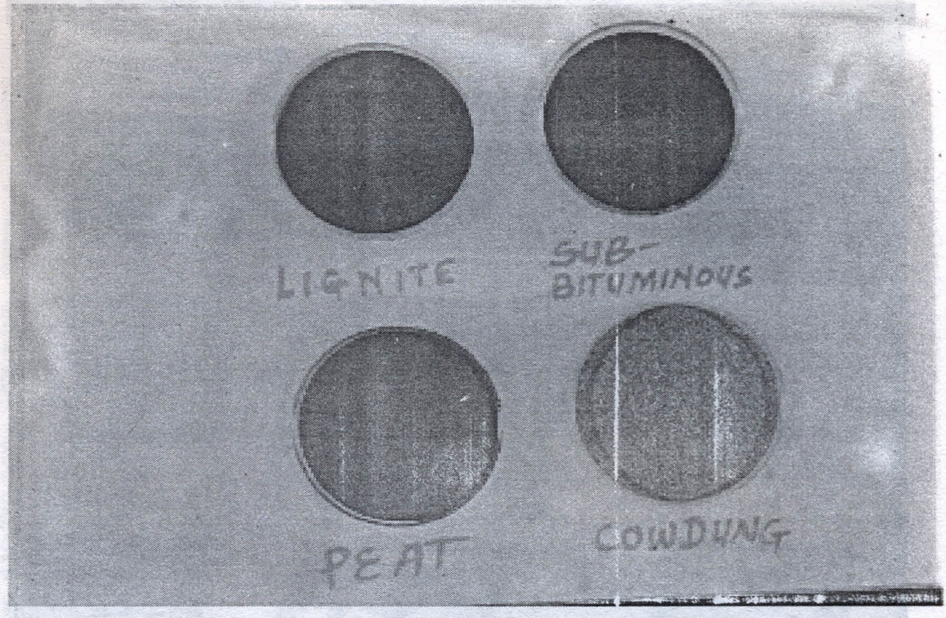


Plate 7: *Four different base carriers for incorporation of* Rhizobia *production.*

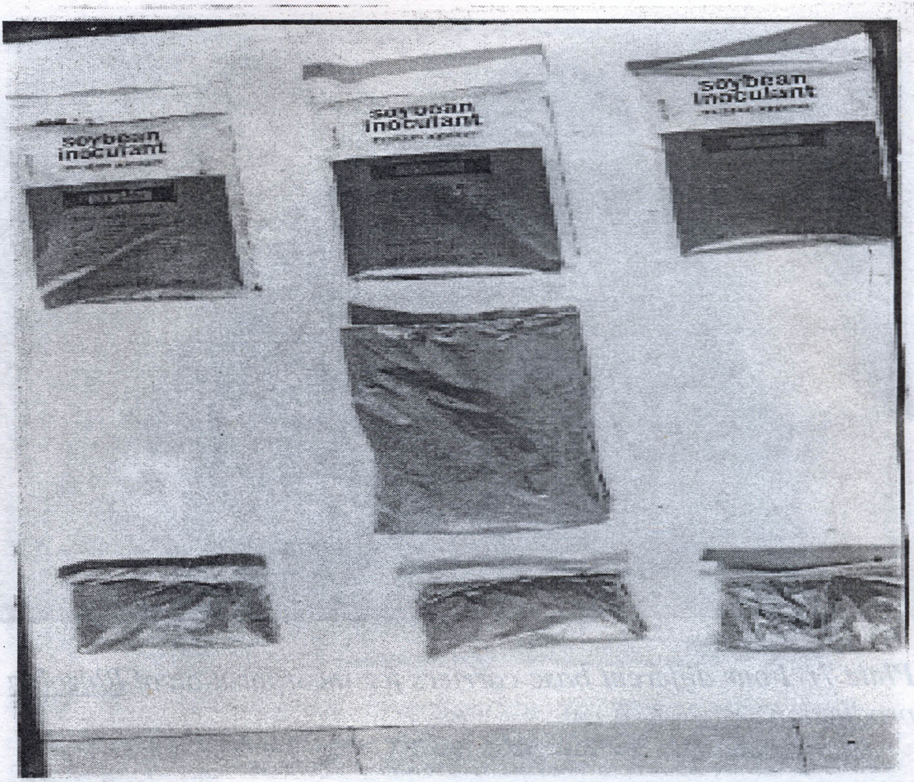


Plate 8: Well-bagged <u>Rhizobium</u> inoculants for commercial use in legume inoculation by farmers.

Thus, we have now made available both the raw materials and the technology for establishing a *Bradyrhizobium* inoculants industry that can revolutionize legume farming in Nigeria. The inoculants was code-named Ife *Bradyrhizobium* Inoculant (IBI).

These root nodule bacteria can improve yields of legumes (cowpea, soybean and groundnut) by 50-70% (Oloke and Odeyemi, 1988). This research output earned this author the National Merit Award for Excellence in Science and Technology in1990. The financial value of the award was used to institute the Prof. Olu Odeyemi Prize for the best graduating student in the department of Microbiology since 1990.

Plate 9: *Field plot investigation to determine the nitrogen fixing ability of some strains of Bradyrhizobium on a farmer's farm.*

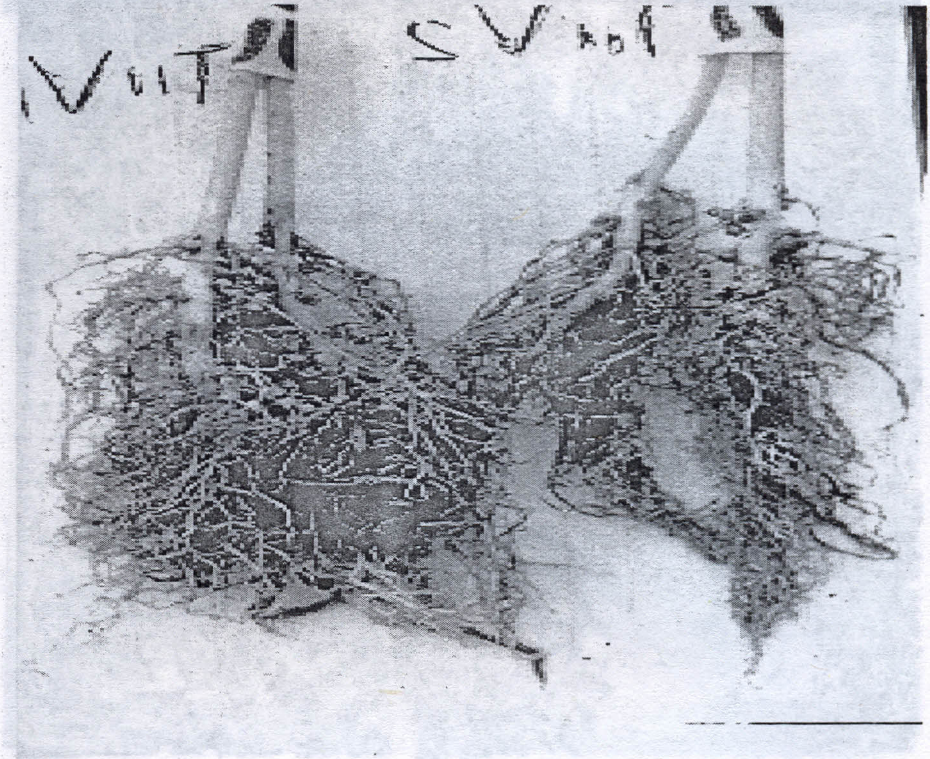


Plate 10: Luxuriant rooting system of a well-nodulated cowpea plant that contributes significantly to soil fertility.

A successfully establishment of a rhizobia inoculant industry in Nigeria would have considerably profound and revolutionizing effects on Nigerian agriculture and socio-economic life in many ways. Rhizobia are special bacteria responsible for the formation of proteins in legumes such as cowpea, soybean and groundnut.

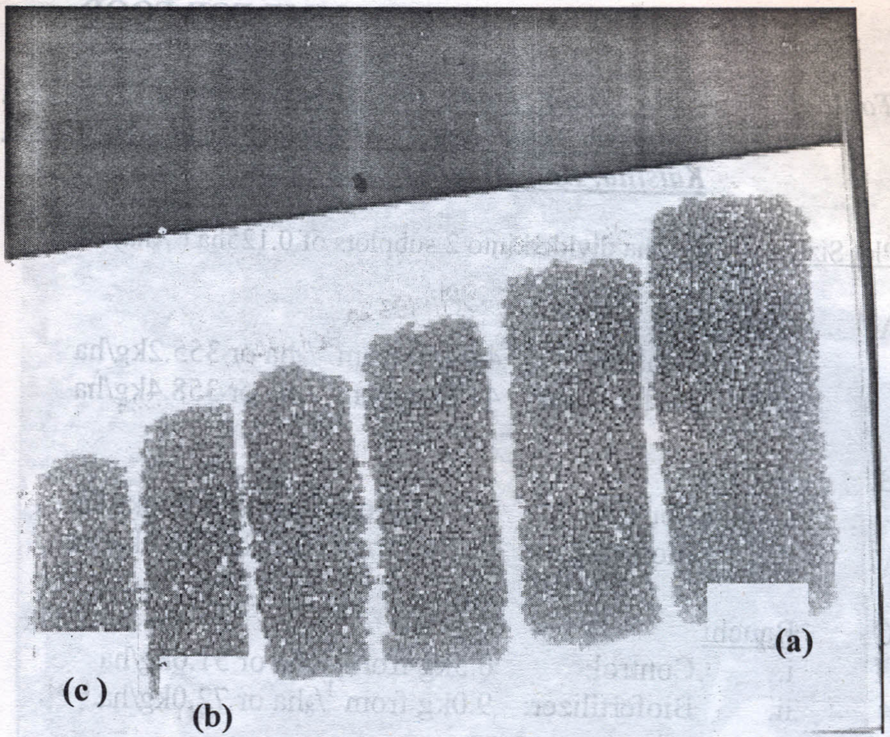


Plate 11: Varietal differences in cowpea yields when inoculated with the same strain of <u>Bradyrhizobium</u>

- *(a) Inoculaated Ife Brown cowpea*
- *(b) Cowpea fertilized with inorganic N*
- *(c) Uninoculated and unfertilized cowpea*

The Food and Agriculture Organization of the United Nations (FAO) is now patronizing our biofertilizer for prosecuting the National Special Programme for Food Security of the Federal Government. Some of their tentative results are shown on Table 10. Thus, for the first time in Nigeria, the FAO in Abuja has used our Rhizobium inoculant to enhance the yields of cowpea by about 50% in Niger, Nasarawa, Katsina, Bauchi and Kogi States during the 2004 cropping season (FAO-Abuja, 2004).

NATIONAL SPECIAL PROGRAMME FOR FOOD SECURITY/FAO, ABUJA (2004)

Table 10: ***Yield Data from the Demonstration Trial on Professor Odeyemi's Biofertilizer in Nasarawa, Katsina, Bauchi and Kogi States***

Plot Size: 0.25ha divided into 2 subplots of 0.125ha ($^1/_8$ha) each.

A. Nasarawa

i.	Control:	44.4kg from $^1/_8$ha or 355.2kg/ha
ii.	Biofertilizer:	44.8kg from $^1/_8$ha or 358.4kg/ha

B. Katsina

i.	Control:	93.2kg from $^1/_8$ha or 735.6kg/ha
ii.	Biofertilizer:	98.5kg from $^1/_8$ha or 788.0kg/ha

C. Bauchi

i.	Control:	6.5kg from $^1/_8$ha or 51.0kg/ha
ii.	Biofertilizer:	9.0kg from $^1/_8$ha or 72.0kg/ha

D. Kogi

i.	Control:	48kg from $^1/_8$ha or 384kg/ha
ii.	Biofertilizer:	64kg from $^1/_8$ha or 512kg/ha

Production of Compost Fertilizer from Solid Wastes

We were the first Nigerian scientists to mechanize compost fertilizer production from food wastes, refuse and other solid wastes.

Plate 12: *Dumped and unsorted refuse at the SPDC waste composting site at Ughelli, Delta State.*

Plate 13: *Sorted refuse ready for the grinding mill at the SPDC composting site at Ughelli, Delta State.*

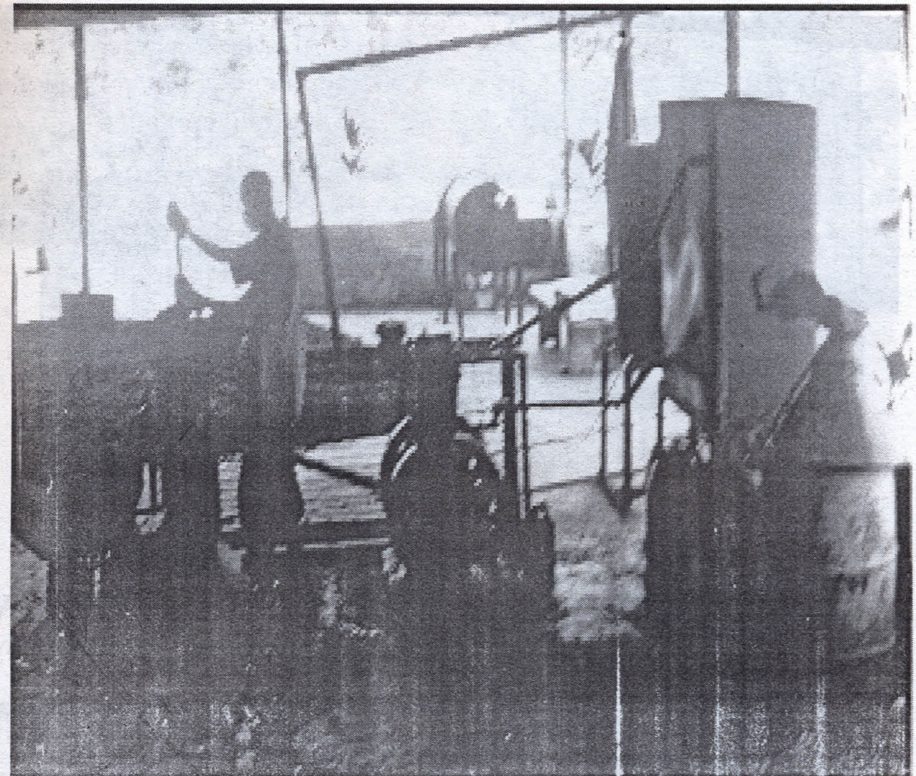


Plate 14: *Decomposable organic wastes being subjected to pulverization by the mechanized grinding machine.*

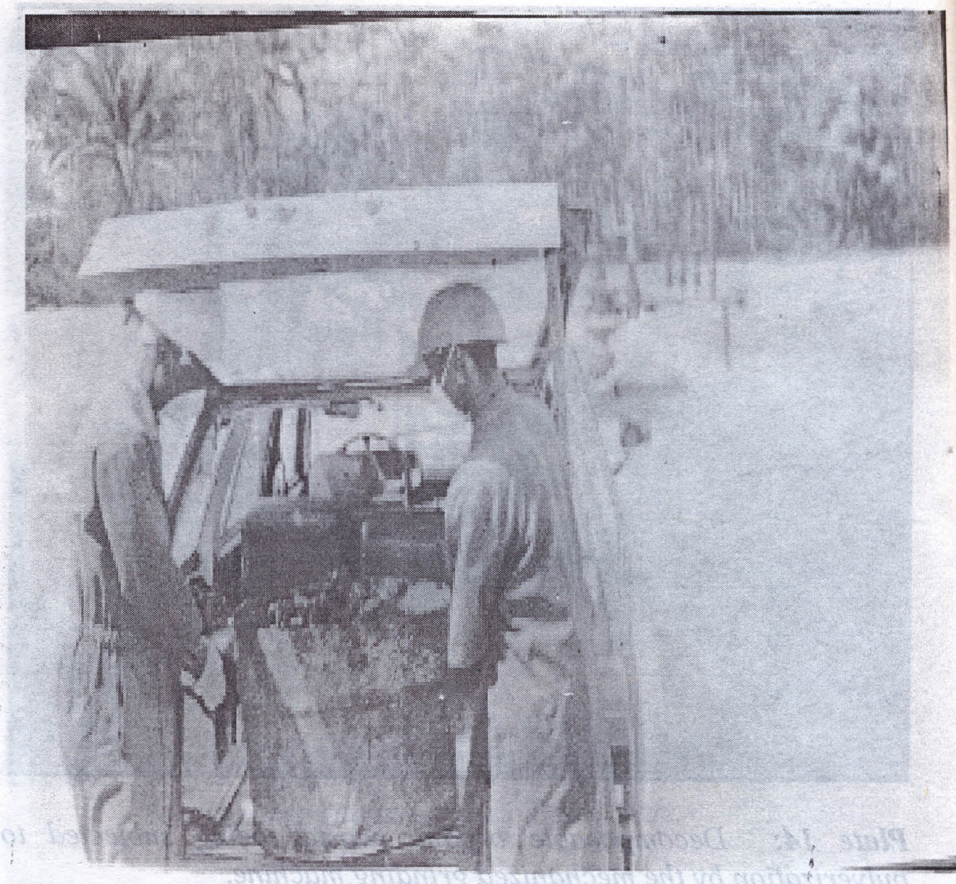


Plate 15: *Cow dung as microbial inoculant for refuse composting.*

Plate 16: *Compost mould being turned over for proper aeration and moistening to accelerate the composting process.*

Plate 17: Composted refuse undergoing maturation.

Plate 18:* *Dark-brown matured compost being bagged for use.

Plate 19: *Field plot investigations to determine the yield enhancement or fertilizer value of the compost, using cowpea as a test crop, at the Obafemi Awolowo University Teaching & Research Farm, Ile-Ife.*

The matured compost fertilizer has been applied to crops such as maize at the International Institute of Tropical Agriculture (IITA), Ibadan, and the Department of Agronomy of the University of Ibadan, Ibadan, where more than 50% increase in yield has been achieved when compared with the untreated maize plots. Similarly, field tests and trials with cowpea, cassava and various vegetables at the Department of Soil Science of Obafemi Awolowo University, Ile-Ife, have resulted in considerable increases in yields when compared with the untreated crops.

Plate 20: *Harvesting of the cowpea seeds from the different experimental treatments.*

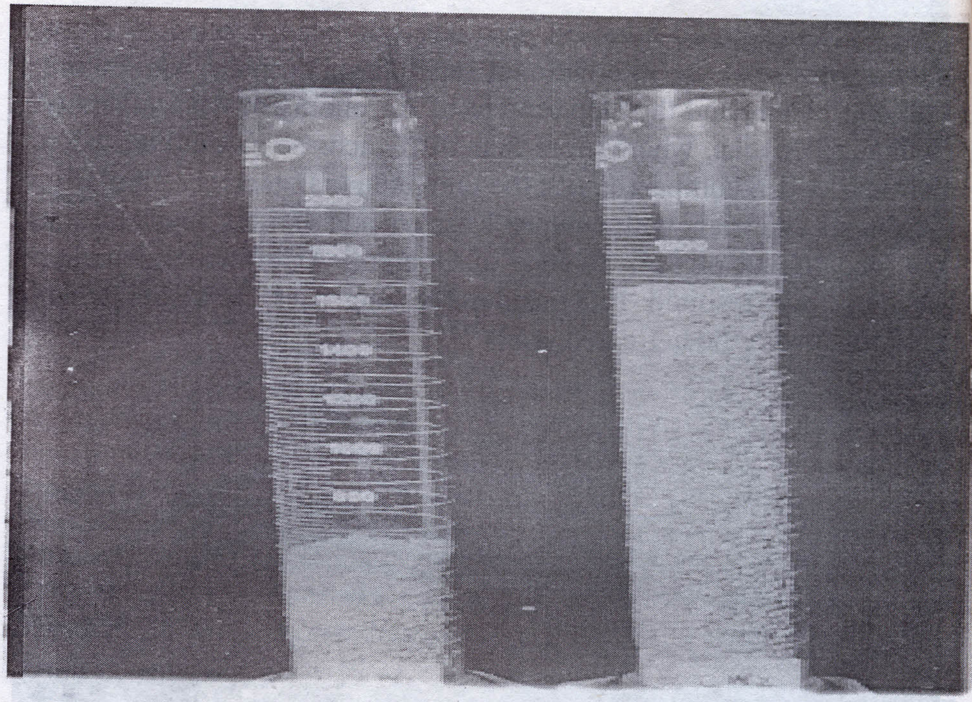


Plate 21: *Enhanced cowpea yield (130kg/ha) in plot treated with 200kg/ha compost (right) compared with 57kg/ha in plot amended with 200kg N/ha of uncomposted waste.*

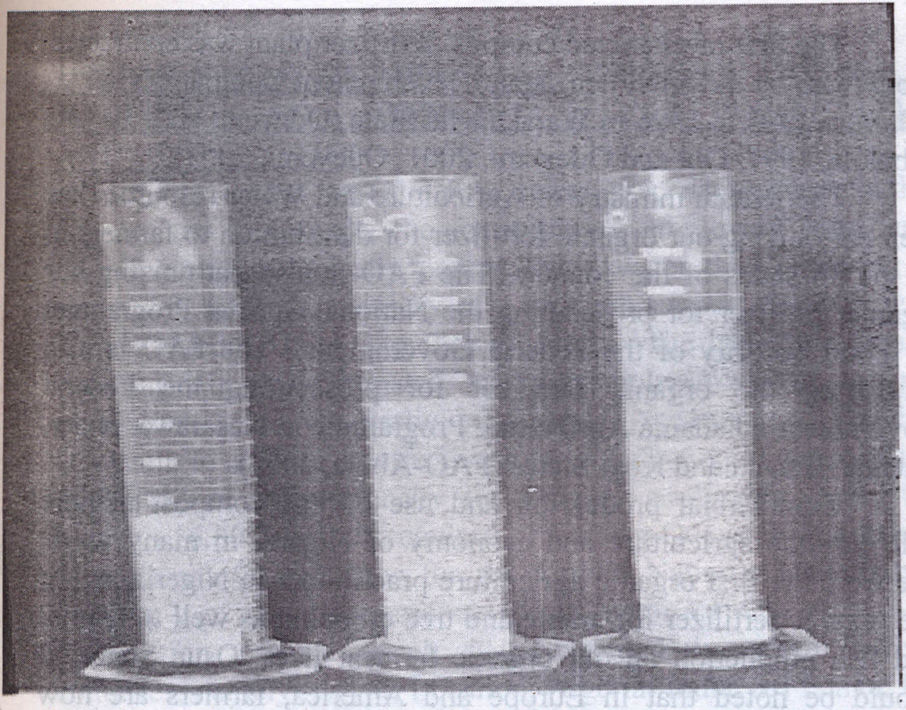


Plate 22: Pea yields of cowpea treated with organic fertilizer (130kg/ha) (right), ammonium sulfate/inorganic fertilizer (98kg/ha) and unfertilized control treatment (61kg/ha) (extreme left).

Plate 23a: Cassava plot treated with 200kg N/ha of compost fertilizer gave a root yield of 33.4kg/ha

Plate 23b: Cassava control plot Without organic fertilizer with a root yield of 11.7kg/ha

The first mechanized compost fertilizer plant was contracted to our team by the Shell Petroleum Development Company Nig. Ltd. from 1993 to 1996 in Warri, Delta State (Odeyemi and Babalola, 1997; Obi and Odeyemi, 2001; Odeyemi, 2003).

The federal ministry of Agriculture and Water resources has been patronizing our organic fertilizer for distribution to farmers in all the 36 states of the country. The FAO is also patronizing our organic fertilizer for prosecuting the National Special Programme for Food Security of the Federal Government. The FAO is also employing the organic fertilizer for prosecuting the Federal Government's Fadama Agriculture Programme in Nasarawa, Niger, Katsina, Bauchi and Kogi States (FAO-Abuja, 2005).

Commercial production and use of this compost manure will enhance agriculture and economy of Nigeria in many ways. We were the first organic agriculture practitioner in Nigeria, as we use organic fertilizer for arable and tree cropping as well as animal and fish production on our organic farm at Ilesa, Osun State. It should be noted that in Europe and America, farmers are now practising non-chemicalised agriculture as food produced through organic farming is believed to be safe and non-toxic to the soil and to humans. Our organic fertilizer was used in most of the 3,000 Secondary Schools in Osun State to boost the school agriculture programme during the year 2002 growing season. The Nigeria Farmer's Congress, Osun State, and many private farmers have also used our **ENPOST FERTILIZER** during the past 10 years. Our research and development efforts on organic fertilizer earned this author the National Merit Award of the Raw Materials Research and Development Council (Abuja) in 2006.

USE OF SEEDS OF MORINGA OLEIFERA AND SOLAR RADIATION FOR DRINKING WATER PURIFICATION AND DISINFECTION

This author was the first scientist to demonstrate both in Nigeria and in Canada, the feasibility of employing sunshine to disinfect bacteriologically contaminated water thus rendering the water safe to drink, courtesy of a research support funding by the United Nations University, Tokyo, Japan. The technique involves exposing the contaminated water sample to sunshine in a transparent glass or plastic container. According to Professor Odeyemi, to achieve an effective solar disinfection of water, at least 600W/M2 of solar intensity for 5 hours, preferably from 10.00 hours to 16.00 hours are required. Professor Odeyemi who was the Institutional Co-ordinator for the United Nation's University in Nigeria was the International Co-ordinator of the solar water disinfection project which was executed in seven different countries, namely: Egypt, Lebanon, Nigeria, India, Sri Lanka, Peru and Columbia. The project which was based at McGill University, Montreal, Canada, was executed from 1985 to 1986. Professor Odeyemi was also the first Nigerian scientist to demonstrate the feasibility of employing the seeds of Moringa oleifera for coagulation and clarification of turbid water (instead of alum) prior to the exposure of the supernatant to sunshine for disinfection.

A vigorous diffusion and adoption of this simple but important technology will benefit humanity considerably, most especially the 2 billion peasants inhabiting the rural areas of developing countries who have no access to treated water supplies. According to the WHO, 80% of all diseases are caused by impure water and poor sanitation.

In August 1992, the UNDP and the United Nations Fund for Population Activities (UNFPA) commissioned Professor Odeyemi to run workshops for representatives of all Local Government Areas of Old Ondo and Bauchi states on the use of the seeds of Moringa oleifera for water purification as a means of diffusing this important technology to Nigerians. Similar workshops were later to be held in other states of the Federation as a means of reducing cases of water-borne diseases in the country.

ENVIRONMENTAL PROTECTION

We have been involved in the protection of the Nigerian environment in the following ways:

(a) Control of river blindness (onchorcerciasis) disease in the Federal Capital Territory (FCT) by river dozing to kill the insect vector (Simulium or blackfly) of the disease, using DDT and later abate insecticides. Professor Odeyemi's research showed that DDT which was used for river dozing from 1966 to 1986 (20 years) was refractory i.e., persistent in the environment, as relatively high concentrations of the insecticide DDT were detected in the soil, water, plant and human blood samples taken at the FCT. Hence, we recommended the use of the insecticide abate which is more biodegrade than DDT for river dozing to control the dreaded river blindness. Hence, river blindness disease is now being more safely controlled at the FCT than before. We were also responsible for collecting baseline data on the water quality of the 24 rivers and streams scattered all over the FCT, and suggested the damming of the Lower Usman River to provide drinking water supply to the FCT.

(b) We investigated the biodegradability of many of the commonly used pesticides in Nigeria (such as gammalin 20, lindane, thiram, vetox 85, captan, malathion) to suggest guidelines as to the persistence, safety, toxicity and proper use of these pesticides in Nigeria. These studies are essential because some of these pesticides possess imperiling properties such as oncogenicity, terato genicity, fetoxicity, mutagenicity, carsinogenicity and biological refractoriness.

(c) We have collected various data and written a United Nations University – published treatise on the various reasons and ways of misuse of pesticides in developing countries, including suggestions on the proper application and safe use of pesticides.

(d) We have carried out various baseline studies and environmental impact assessments for protecting the fragile mangrove forest of Nigeria Delta on behalf of the Federal Government and the Shell Petroleum Development Company of Nigeria Limited. Projects and areas studied include Dodo North Field, Aki-Ovwe, Owviamuge, Belema Field and Trans-Ramos Pipeline Project areas. In all these fields, all biotic and abiotic data were documented to suggest mitigating and ameliorating measures for protecting the mangrove ecosystem in spite of the oil drilling activities.

(e) We studied the environmental impact of the industrial waste water from the International Breweries Plc., Ilesa, in Osun State on the water quality of the receiving stream during a one year period of continuous monitoring of the biotic and abiotic characteristics of the waste water.

Subsequently, in collaboration with Professor M. O. Ogedengbe of Civil Engineering Department (O.A.U., Ile-Ife), we constructed two big oxidation ponds for treatment of high BOD sewage of the IB Plc. Hence, the brewery's industrial effluent is now being quite adequately treated prior to its discharge in the Omi-Asoro, the receiving stream, thus protecting the water quality of the stream and its numerous users downstream.

CONCLUSION AND RECOMMENDATIONS

If microorganisms provide the basis for the life and life support systems; If microorganisms provide us with a vast array of goods and services as enumerated above; if microorganisms are the basis of great industries; if they are contributing significantly to national economies; if the microbial diversity market and potential is huge (about 150 billion dollars annually); if the success of biotechnology relies heavily on the diversity of microorganisms; WHY are the study and the conservation of microorganisms not receiving deserved and appropriate support from policy-makers?

In this regard, the following recommendations are apt, incisive and instructive:

(a) Given the endless combinations of terrestrial, aquatic and oceanic habitats and such enormous potentials of secondary metabolite production in microorganisms, and the opportunities available for manipulation of the types of quantities produced in the laboratory, the biotechnology industry has a tremendous resource at hand for the discovery of new chemicals for biotechnological applications. Therefore, the study of microbiology and biotechnology should be given adequate funding and publicity like the field of information and communication technology.

(b) There is an urgent need for the Federal Government to establish an Institute for Biological Resources Conservation that will be saddled with the responsibility of assessment, conservation and preservation of our biological assets with particular attention to microbiological resources. The Institute should also devise reliable techniques for quantifying the economic values of biodiversity.

(c) It is also important to emphasize biosystematics in our study of plants, animals and microorganisms so that the contribution of taxonomy in successful applications of bio-resources especially microbial resources to agriculture, medicine, industry and goods production can be appreciated.

(d) The United Nations University (UNU, Tokyo, Japan) should establish an International Institute for Biosystematics to develop identification services and training courses in taxonomy. Such an Institute may be sited in a well-established University in Nigeria, partly because of contiguity to the International Institute for Tropical Agriculture (IITA, Ibadan). But, principally considering geography, macro- and microclimates, physico-chemical parameters, demography and biotrophy of Nigeria, there are endless combinations of terrestrial, aquatic and marine habitats each harbouring specific and novel communities of plants, animals and in particular microorganisms from which species with different metabolic potentials can be isolated. Such an Institute should work closely with UNU – Institute for Natural Resources in Africa (INRA) so that information on taxonomy and culture collections are globally coordinated and habitats are protected as unique organisms could disappear before knowing what was lost.

(e) Earlier classical economists had regarded income as the return on land, labour and capital, largely ignoring the role of biological resources in generating income. Neo-classical economists say there are no methodologists to cost the total economic value of biological diversity. So, it is assigned zero price in the national accounts. The national and international biological societies should assist in quantifying the economic value of biodiversity so that net national product (NNP) incorporating biodiversity can provide a more useful method of economic performance than the usual gross national product (GNP).

(f) Nigeria is long overdue for the establishment of a National Centre for Culture Collection where microorganisms of economic importance are stocked and maintained. As more than 80% of all antibiotics are produced from soil microorganisms, our soils should be well-protected as an extremely valuable national asset.

(g) Nigeria should embrace the use of organic fertilizers for the production of safe and internationally acceptable foodstuff. Massive application of organic fertilizer in conjunction with the appropriate afforestation programme can ameliorate the desertification problems that has seriously afflicted 11 Northern States of Nigeria as the desert advances southward at the rate of 0.6km/yr.

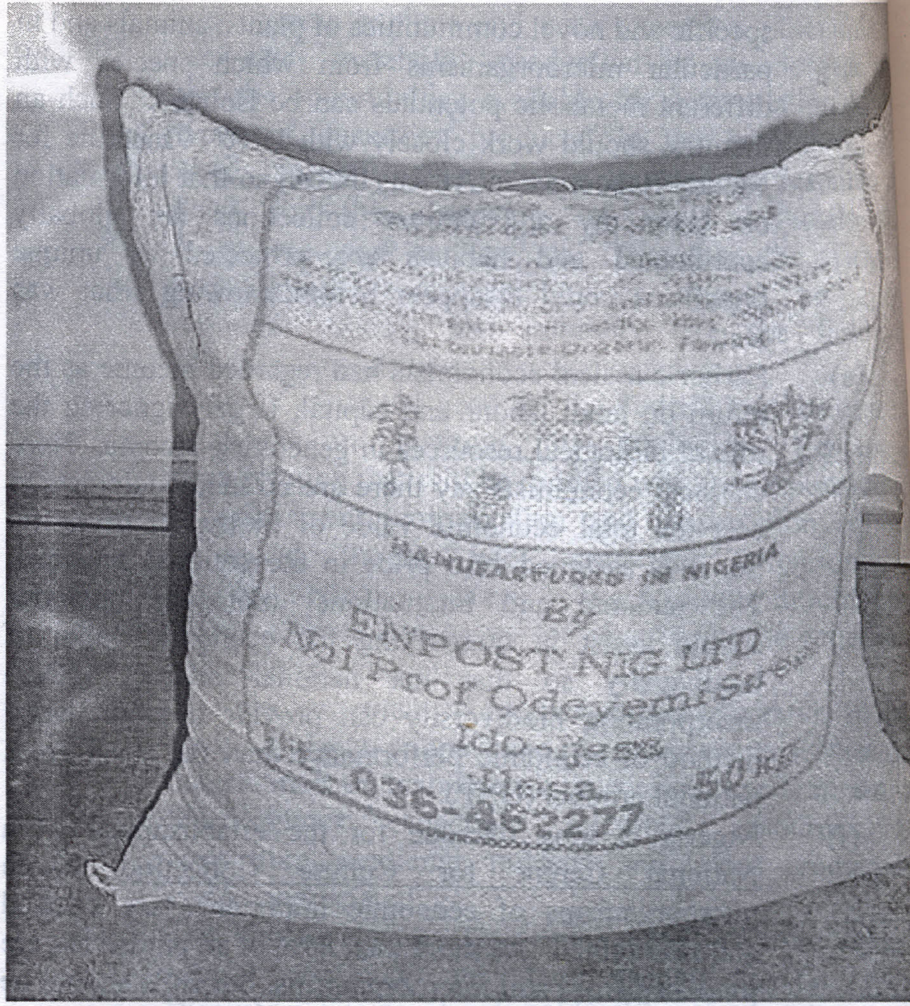


Plate 24: ENPOST organic fertilizer for improved, sustainable and safe agricultural productivity

(h) Nigeria should also promote the use of Rhizobium inoculants to enhance yields of cowpea, soybean, groundnut, etc. in order to enhance soil fertility, meat and milk production, eradicate protein energy malnutrition or kwashiorkor and probably bring back the famous Kano Groundnut Pyramids of the early 1960s.

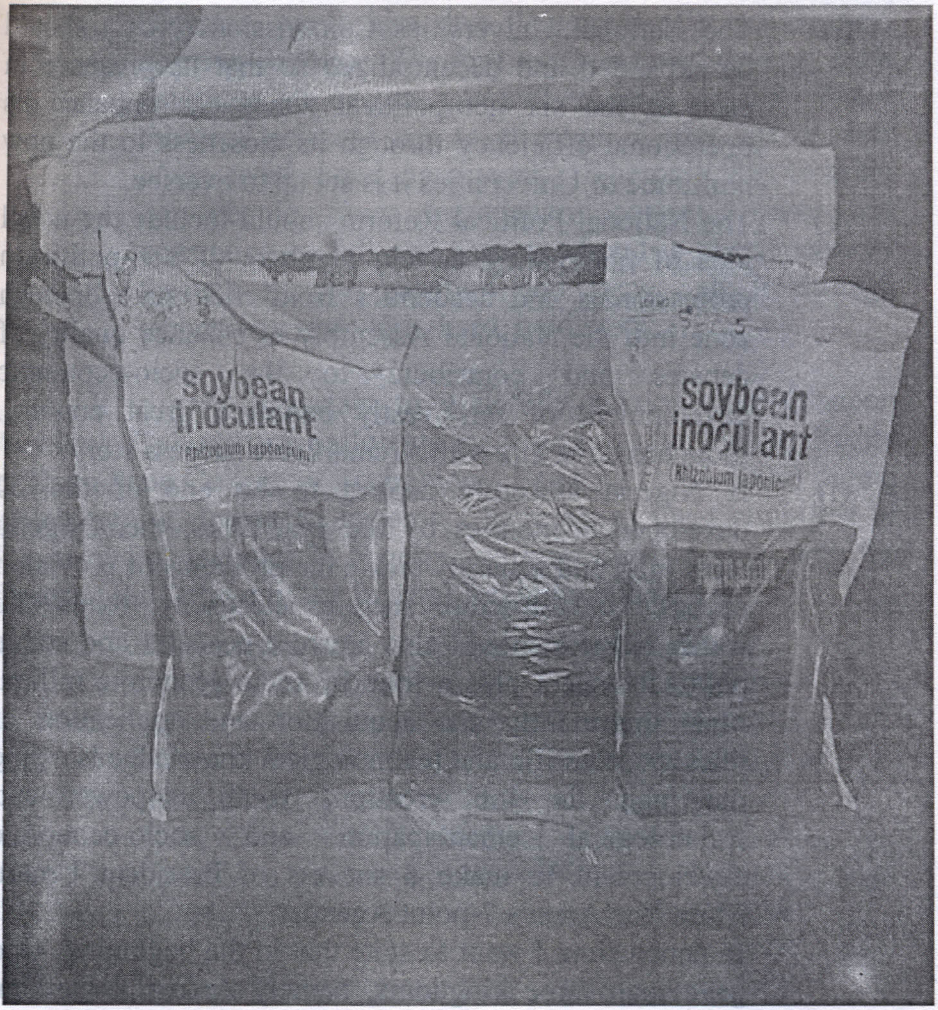


Plate 25: Biofertilizers for legume inoculation

(i) In Nigeria, academics are grossly underutilized in nation building. Nigerian academicians and other professionals should be fully engaged in solving our socio-economic problems instead of looking up to foreigners for our salvation. If our teaching and research programmes are inadequate, let us review, re-orientate and generously fund them to achieve our national goals.

(j) The National Universities Commission (NUC) should be expanded and decentralized so that its presence in each of the six geo-political zones can enhance its operational efficiency through its closeness to the now multitude of Universities it is set up to oversee.

(k) The National Political Reform should include the novel idea of nominating certain numbers of non-politician professionals and academics from each state or each zone into the National Assembly to enhance quality of debates and contribute to the socio-economic development of this vastly endowed great country. India has done this with a remarkable success story.

(l) If Nigeria sincerely aspires to be one of the 20 developed economies by the year 2020, then Nigeria must fully and squarely tackle the problems of provision of basic infrastructure such as electricity, roads and water, Nigeria should also create a peaceful and stable political system plus a friendly socio-economic milieu. Most importantly, the acquisition and application of relevant scientific and technological knowledge is a sine qua non for job creation, youth empowerment, technological emancipation and socio-economic development to make a success of President Umaru Musa Yar'Adua's 7-point Agenda.

In conclusion, I want to state that in the beginning, God gave man three kingdoms, namely Animal Kingdom, Plant Kingdom and Mineral Kingdom. Later God added the fourth Kingdom, i.e. Synthetic or Technology Kingdom which now controls and manipulates the other three kingdoms. Nigeria is unable to benefit from the fourth kingdom, because we have failed to embrace science, engineering and technology. In view of this, I hereby wish to propose the formation of an Association for Scientific Emancipation of Nigeria (ASEN). An American Negro Scientist, Mr. George Washington Carver, made 107 products from sweet potato alone and in 1921, Mr. Booker t. Washington, U. S. Negro educator, wrote him thus "*I cannot offer you money, position or fame. The first two you have, the last, from the place you occupy, you will no doubt achieve. These things, I now ask you to give up! I offer you in their place, work, hard, hard work*". The only way to bring our people from degradation, poverty, waste and corruption to full and sane manhood is not necessarily through money, position and fame. It is through technology and work, hard, hard work.

It is very important to gratefully acknowledge Obafemi Awolowo University for allowing me to serve as the Pioneer Rector of Osun State College of Technology, Esa-Oke (1993-2000) during which period, I rose to become Chairman of the Committee of Heads of Polytechnics in Nigeria and was also honoured with the Order of the Officer of the Federal Republic (OFR).

REFERENCES

1. Alexander, M. 1991. Introduction to soil microbiology. Krienger Publishing Company, Malabar, Florida.
2. Alofe, F. V., 1985: The general characteristics and cultivation of some Nigeria mushrooms. Ph.D. Thesis. Obafemi Awolowo University, Ile-Ife, Nigeria.
3. Alofe, F. V., Odeyemi, O. and Oke, O. L., 1996: Three mushroom species from Nigeria: Their proximate and mineral composition. Plant Foods for Human Nutrition, 45:63-73.
4. Alofe, F. V., Odeyemi, O. and Adebambo, F. O., 2001: Toxicity of edible wild mushrooms in Nigeria. African Crop Science Conf. Proc. 5:579-583.
5. Chrispeels, M. J. and Sadawa, D. E. 2003. Plants Genes, and Crop Biotechnology. Jones and Barlett Publishers, Boston, MA, U.S.A.
6. C.S.C. 1979. A Chinese biogas Manual. International Technology Publication Ltd. The Commonwealth Science council, London.
7. Dobereiner, J. and A. B. Campello, 1977: Importance of legumes and their contribution to tropical agriculture. In: A Treatise on Dinitrogen Fixation. (Eds. R. W. F. Hardy and A. H. Gibson). John Wiley and Sons, New York.
8. Dawson, R.C. 1970: Potential for increasing protein production by legume inoculation. Plant and Soil, 32:555-673.
9. FAO/National Special Programme for Food Security. 2004. No. 3, Oguda Close, Off Lake Chad Crescent, Maitama, Abuja, Nigeria.
10. Hawksworth, D. L. 1991: The fungal dimension of biodiversity: magnitude, significance and conservation. Mycological Research, 95:641-655.
11. Komagata, K. 1999. Microbial diversity and the role of culture collections. Pure Appl. Chem. 70, No. 11.
12. Lee, R. E. 1980. Phycology. Cambridge University Press. Cambridge.

13. Lockwod, L. B. and Schweiger, L. B. 1967: Citric and itaconic acid fermentations. In: Microbial Technology (Ed. H. J. Peppler) Reinhold, New York, Pp. 183-199.
14. Nelson, J. H. and Richardson, G. H. 1967: Molds in Flavour production. In: Microbial Technology (Ed. H. J. Peppler) Reinhold, New York. Pp. 82-106.
15. Obi, A. O. and Odeyemi O., 2001: Evaluation of the fertility status of food wastes. African Soils, Vol. 32, No. 1, Pp. 17-26.
16. Ogunseitan, O. 2005. Microbial Diversity. Blackwell Publishing, Malden, MA. U.S.A.
17. Odeyemi, O., 2003: Review of the available technologies for the manufacture of organic fertilizers: Problems and prospects. In Organic Fertilizer Sourcing, Development and Quality Control Standards in Nigeria. (V. O. Chude et al., Eds.). FAO/National Special Programme for Food Security/Federal Ministry of Agriculture and Rural Development, Abuja. Pp. 20-29.
18. Odeyemi, O. 2005: Microbiology and the Nigerian environment, Paper delivered at the Nigerian Biotechlogy Conference, Abuja.
19. Odeyemi, O. 2007: The Impact of Microorganisms on Economic Development. Faculty of Science Public Lecture Series; Adekunle Ajasin University, Akungba.
20. Odeyemi, O. 2007: Microbiology, Science and Sustainable
Development. Keynote Address Delivered at the 31st Annual Conf. Nig. Soc. Microbiol; Usmanu Danfoddiyo Univ., Sokoto, Oct. 2007.
21. Odeyemi, O. 2005: Unseen Allies of Economic Development. Post-graduate School Interdisciplinary Research Discourse 2005, University of Ibadan, Ibadan.
22. Odeyemi, O., 2005: Option in waste conversion: Biogas and Organic Fertilizer Production. Paper presented at a Seminar organized by the Ogun State Ministry of Environment, Abeokuta on 3rd February, 2005.

23. Odeyemi, O., 1991: Protein energy malnutrition in Africa: Bradyrhizobia to the rescue? In: The Role of Biology in Resolving the Food Crisis in Africa (Eds. A. T. Ba and M. Ndoye). African Biosciences Network, UNESCO-BREDA, Dakar, Senegal. Pp. 760-762.

24. Odeyemi, O. and G. O. Babalola, 1997: Segregation and composting of food wastes. Final Report submitted to the Shell Petroleum Development Company, Nig. Ltd., Warri, Nigeria, by ENPOST Nig. Ltd., Ile-Ife.

25. Odeyemi, O. and S. O. A. Olaoye, 1984: The Siam plant (Eupatorium odoratum): Biogeography and possible use as an energy plant. United Nations University, ASSET 6(7):21-24.

26. Oloke, J. K. and O. Odeyemi, 1988: Effects of some Nigerian Brayrhiobium inoculants on the performance of three cowpea cultivars (Vigna unguiculata) in two field plots. Biology and Fertility of Soils, 6:178-182.

27. Peppler, H. J., 1967: Yeast Technology. In: Microbial Technology (Ed. H. J. Peppler) Rehinhold, New York. Pp. 145-171. Rehm, H. J. and Reed, G., 1981. Biotechnology Vol. 1, Verlag Chemie. Weinheim. Deerfield Beach, Florida.

28. Tiedje, J. 2008. Priorities for Microbial Biodiversity Research. Centre for Microbial Ecology, Michigan State University, East Lansing, U.S.A.

29. Ware, G. W. 1978: Pesticides Theory and Application. W H. Freeman and Company. San Francisco.

30. Wery, J. and P. Grignac., 1983: Uses of legumes and their economic importance. In: Technical Handbook on Symbiotic Nitrogen Fixation: Legume/Rhizobium. FAO, Rome.

31. Zedan, H., 1998. www.wfcc.info/ICCC7/keylectu.html.