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WORD BECOMING FLESH: THE IMPERATIVES FOR PROCESS BIOTECHNOLOGY DEVELOPMENT IN NIGERIA

BY

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WORD BECOMING FLESH: THE IMPERATIVES FOR PROCESS BIOTECHNOLOGY DEVELOPMENT IN NIGERIA

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PROLOGUE

In the book of St John, Chapter 1, Verse 1 of the Holy Bible, it is written: *"In the beginning was the Word, and the Word was with God and the Word was God."* We are also told in Genesis, Chapter 1, Verses 26 and 27, *"And God said, Let us make man in our image, after our likeness, and let them have dominion over the fish of the sea, and over the fowl of the air, and over the cattle, and over all the earth, and over every creeping thing that creepeth upon the earth. So God created man in His own image, in the image of God created He him; male and female created He them."* (KJV)

At the time of creation, the Word remained the Word. There was no need nor time for the Word to change its status. Everything appeared perfect; indeed all was perfect. Then came the bombshell. Man, whom God created sinned against God by disobeying Him. The perfection that hitherto existed in creation was altered and there arose imperfection. With this outset of imperfection, man became separated from God because the two had become incompatibles; one good, the other evil. Meaningful interaction was also impossible because of the gulf created between God and His creation, man, by the sin committed. It was impossible and it is still not possible for good and evil to dwell together. God was displeased with the severed relationship. As a fulfilment of his promised punishment for man's disobedience, it is recorded in the book of Genesis, Chapter 4, Verses 1 and 2 thus: *"And ADAM knew Eve his wife, and she conceived, and bare Cain, and said, I have gotten a man from the LORD. And she again bare his brother, Abel. And Abel was a keeper of sheep but*

Cain was a tiller of the ground." So, man's sufferings started with specialization in the all important Food/ Agricultural sector. Hence, the beginning of man's fending for himself and *indeed the beginning of the use of technology by man.*

A quick look at one of the many definitions of technology, as agreed upon at a German Foundation - sponsored International Workshop in Kumasi, Ghana, in 1972, at which I had the privilege to represent Nigeria, showed the linkage of technology with man's efforts to survive. It makes sense that this survival should be linked with man's initial sin and God's punishment of man. This definition of technology, from a socio-cultural angle, is as follows: *"Technology is the component of the culture of a people which enables them to extend their human, physical and mental powers so as to adapt, utilize and ultimately control the physical and social environment for the sustenance of life, the survival of the community and the provision of conveniences for the community."* Other components of the culture of a people apart from technology are Health/ Medicine, Food/Agriculture, Shelter/Housing, Transportation, Power/Energy, Education and Music/ Dancing/Drama. It should be noted that technology is one component that pervades all the other components and therefore its prime importance is not in doubt.

It is obvious from history that the survival and well-being of any group of people in this world and the maintenance of the culture depend largely on the development of its technology. There is no doubt that the spiritual being in us is the engine of our operations. Therefore, we cannot be wrong if we say that Human development generally and Technology development, in particular can be seen as related to the roots of our creation, which is spiritual. Thus, our human development and our spiritual being are not separate entities. Therefore, we cannot ignore the historical

link of life and survival from the time of the sin of man with technology and its development. That was the beginning of man's having to fend for himself. We must note that after man had sinned against God, the question of the survival of man became a life-long task. He needed to continue to look back in history (of creation) for a solution to its survival through acquisition of technology and its development.

1.0 INTRODUCTION

The thrust of this inaugural lecture is to find out what propels a nation towards process biotechnology development and indeed any technology development. For centuries, it has become the preoccupation of nations to find solutions to the problems to their survival and good living. This has resulted in nations trying all types of political systems to govern themselves and all available technologies to use including the use of robotics with no clear-cut solutions to their problems. We cannot forget that the latest of these developed technologies, namely, information technology, has made the world a global village and yet our country, Nigeria, still has no grassroots development. You can now see the contradiction.

It must be realized that any attempt at fostering technology development without recourse to the origin of man is a task in futility. The question we cannot ignore at anytime is: "Who are we as human beings and what is the purpose of our lives?" I believe that the Word becoming Flesh has a significance of a development process and we must see its importance in helping out in our physical survival through our cultural development especially technology development in a world of sin.

Many of us still believe that we are in the Garden of Eden where there was no need to make any effort before living well because everything needed in the Garden was provided. We do not realize that since man sinned, there has been a need for man to transform himself into a *"development being"* by using positively all the talents contained in his human, physical and mental powers, given by God. It must be realized that since the first sin in the Garden of Eden, a yoke has been placed on man. Until this yoke is removed totally from all men here on earth, we must continue to develop our technologies both to sustain ourselves and also to improve our living standard.

What do I mean by *"Word becoming Flesh"* being imperatives to technology development? It is simply this, that the drastic solution by God (i.e., God becoming Man) to a very serious problem (i.e., the sin of man) is something that is required of us in solving our problem of physical survival which is technology development. Some nations seem to have got it right. But certainly not Nigeria nor indeed other technologically backward nations of the world.

2.0 IMPORTANCE OF KNOWLEDGE AND SKILL IN DEVELOPING, OPERATING AND MAINTAINING TECHNOLOGY

It is now apt to again define technology this time not from a sociocultural angle but as it relates to the importance of knowledge and skill. Technology is the use or application of knowledge primarily derived from the systematic investigation of the forces of nature, (i.e., from natural laws), to satisfy man's needs. Note that knowledge can also derive from empirical means without any theoretical basis. Technology can also be defined as the application of knowledge (whether scientific or not) through the acquisition and use of skills. It is this skill that is art or culture-associated. Skill enables knowledge to be translated or transformed into a useful phenomenon such as improving the quality of life. Skill can only be acquired through practice i.e., by doing or carrying out some actions.

Knowledge can therefore be acquired through *science*, i.e. a methodology involving a systematic investigation of the forces of nature (or natural laws) or through *empirical means* (i.e., trial and error methods). For those of us in the engineering discipline, it may interest us to know that Engineering is an applied science used to develop and sustain technology. The ability to transfer knowledge to technology requires a special skill in visualizing things around us.

Knowledge itself is having facts, skills and understanding that have been gained through learning or experience. It is also having information about something and when this piece of information is known to be true, then the information is a fact.

Technology involves three main activities regarding hardware/equipment, *viz,*

(i) physical production or reproduction of hardware/ equipment,

(ii) operation of such equipment, and

(iii) maintenance or repair of such equipment.

Both knowledge and skill are required in developing, operating and maintenaning technology through production, operation and maintenance of hardware/ equipment.

We should know that technology is actively required in producing wealth for a nation through its use in transforming the nation's raw materials. This is in consonance with the message of my brother Chemical Engineer, the present Dean of the Faculty of Engineering, Prof Olu Ogboja, in his inaugural lecture of 1998, which he aptly titled "The Making of the Wealth Plant." So there is no doubt that Chemical Engineers, if given the best environment and support, are wealth makers. I make bold to say that *development of technology* is *creation of technology* and it has its genesis in the creation of the world by God. We cannot ignore going back to our roots.

3.0 SCIENCE – BASED TECHNOLOGY AS A MEANS OF HARNESSING THE POWER OF NATURE FOR MAN'S NEEDS

From the above definition of technology, it can be seen that technology is either science-based or empirical based. It is the science-based technology that uses knowledge acquired through systematic investigation of the power of nature. For the purpose of this lecture, let us look at some examples of statements arising from natural laws which are equivalent to the power of nature, not in any order of importance:

(i) What goes up must come down (law of gravitational pull)

(ii) Water finds its own level (law of gravitational pull) or (law of natural balance)

(iii) No condition is permanent (principle of nature being in continuous movement)

(iv) Everything is in a state of flux or constant motion (principle of nature being in continuous movement) or (nothing is static)

(v) No machine can work forever (law of non-infinite energy)

(vi) Birds of a feather flock together (the principle of common interest binding people together)

(vii) Opposites attract and likes repel (the law of magnetic pull and repulsion)

(viii) A kilogram of iron is not heavier than a kilogram of feather (law of constancy of same weight irrespective of types of materials)

(ix) No two human beings are the same (principle of dissimilar DNAs in human cells)

(x) The shortest line between 2 points is a straight line (principle of trigonometrical truism)

(xi) The strength of a chain is in its weakest point (principle of no whole can be stronger than any of its weakest parts).

(xii) Nature will always take its course (the law of Karma or the law of retribution)

(xiii) A light object will float while a heavy object will sink (principle of Archimedes)

(xiv) Motion requires a driving force (Newton's law)

I believe that these basic scientific truisms should be inculcated in our children right from infancy as it is done in the developed world so that science (as a methodology) becomes a part of the culture of our people and the right perception of nature can be built up. The use of appropriate toys for our children at the early stage in life can be useful here.

4.0 BIOTECHNOLOGY FOR MAN'S NEEDS IN MEDICINE, ENVIRONMENT, AGRICULTURE AND INDUSTRY (PROCESS)

Let us now take a look at what biotechnology is especially in relation to man's needs. This will be done by taking a look at various definitions of biotechnology.

Biotechnology is the application of biochemistry, biology, microbiology, genetics and chemical engineering to industrial processes and products, medicine, agriculture and to the environment.

Biotechnology is also the conscious scientific and engineering manipulation of whole or parts of products or cultures of biological objects, (plants, animals and microorganisms) including the creation of new properties in the biological objects through the introduction of foreign nucleic acids for the production of valuable goods and services following a thorough scientific understanding of the process to be manipulated.

Also in a narrow sense, biotechnology is a technology based on tissue and genetic engineering, and it has wide applications in the field of agriculture, health, energy, industry, environment and other related fields.

One other definition may suffice, that is:

Biotechnology is defined as the application of 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.

All these definitions put together bring about one common factor which is that biotechnology is useful in medicine (or health), environment, agriculture and industry (or

process). We therefore have specialization in four areas as given below.

(i) **Medical biotechnology (biomedical technology)**
This is that aspect of biotechnology, which deals with medicine, i.e., the health and various physiological activities of man. This includes the mechanical and electro-mechanical simulation of physiological organs in form of artificial structures such as limbs, lungs, heart, liver and kidney. It also includes such topics as control of human parasitic diseases through recombinant DNA technology, new drugs development and application, diagnostics and biologicals, and diagnosis and cure of genetic diseases.

(ii) **Agro-biotechnology (bioagrotechnology)**
This is an aspect of biotechnology which deals with agriculture, both plant crops and animal production. It includes such topics as animal vaccine development, bioinsecticides, biofertilizers, and development and production of such crops as root and tuber, cowpea and soybeans, maize, rice and plantain / banana.

(iii) **Environmental biotechnology (bioenvironmental technology)**
This is an aspect of biotechnology which deals with the environment. It includes such topics as regulatory issues, both in the practice of genetic engineering, and in the use of biotechnology products, and the role of biodegradation and bioremediation in pollution control.

(iv) **Process or Chemical or Industrial Biotechnology (Bioprocess or Biochemical or Bioindustrial technology)**
This is an aspect of biotechnology which deals with chemical processes and industrial production. It includes such topics as fermentation industries (including development of new fermentation products), enzyme

production, industrial typing of microorganisms, industrial raw materials, and food processing. Bioprocess technology is divided into the following subunits: Food, Fermentation, Enzyme reaction and Bioextraction processes.

Many of the definitions and classifications in this section came from the Proceedings of the National Workshop[1] on Biotechnology held in the country in 1993 at Festac '77 (Durbar) Hotel, Lagos. I wish to publicly give acknowledgement to the role played by many of Nigeria's pioneer biotechnologists in the various specializations. Some of these renowned biotechnologists that presented papers at that inaugural National Workshop were Prof Nduka Okafor, Prof E. O. Akinrimisi, Mr. G. A. Solabi, Prof O. K. Udeala, Dr. G. O. Gbenle, Prof S. K. Layokun, Dr. P. O. Ogazi (late), Prof E. O. Oyedipe, Dr. A. G. Lamorde, Prof Adewale Adebayo, Dr. D. K. Olukoya, Dr. S. C. Okpara, Dr. Adeyinka Falusi, Prof Mark Nwagwu, Prof S. K. G. Obi and the presenter of this inaugural lecture.

5.0 THE DEVELOPMENT AND APPLICATION OF PROCESS BIOTECHNOLOGY

I now wish to look at aspects of my own specialization, which is process or industrial biotechnology.

5.1 Role of National Development Plans in Focusing on our Process Biotechnology Development:

It is often said that no nation or individual fails to plan, or plans to fail. However, a poor plan or a plan that is not well articulated is not likely to achieve targets desired. Nigeria has no doubt had many development plans since independence. I want us to take a look at the various national development plans since our independence in 1960 and how these may have affected our process biotechnology development or, generally, industrial development as well as career prospects for chemical/

biochemical technologists/engineers in the country. This is from a macroeconomic viewpoint.

The first National Development Plan (NDP) (1962 – 1968) showed that the emphasis in the Nigerian economy at the time was on *import substitution.* This meant that most of the chemical and allied industries which were foreign-based had their subsidiary branches in Nigeria to carry out mainly finishing operations. For the chemical/biochemical technologists/engineers, the emphasis was on *operating* process plants with little opportunity for developing, designing and fabrication of process plants. Thus, the design knowledge of the chemical/biochemical engineer, which is the core of engineering training, was hardly utilized.

The second NDP (1970 – 1974) also experienced the same thrust, viz, *import substitution* with similar job opportunities for our chemical/biochemical engineers as above. It is, however, important to emphasize that the oil boom in Nigeria during this second plan period further encouraged this philosophy of import substitution because of the availability of foreign exchange and this was to the detriment of self-reliant drive of the nation. It is important to note that during the third NDP (1975 – 1980), the economy had begun to take some " knocks" and the philosophy of the national economic development was beginning to change to *self-reliance and sustainable development.*

By the fourth NDP (1980 – 1985), the economy had really become noticeably depressed and the country had no choice but to encourage self-reliance and sustainable development. The period 1975 – 1985 (i.e. third and fourth NDPs) therefore, witnessed intensification of Nigerianisation of some categories of some businesses including the ownership of some categories of industries. It was important at this stage for the training of our engineers/technologists to adjust to the challenges of the time.

From the fifth NDP period (1985 – 1990), when Nigeria decided on **structural adjustment programme (SAP)**, not only was the economic policy that of **self-reliance and sustainable development**, but also the policy included the encouragement of **entrepreneurship or Work-for-Yourself programmes** for young Nigerians. This necessarily meant that training of engineers/technologists needed to emphasize, more than ever before, courses in business management, humanities, social sciences and business law. During this period, there was the establishment of such development-oriented institutions such as Raw Materials Research and Development Council (RMRDC) on industrial raw materials and National Science and Engineering Infrastructure (NASENI) on science and engineering infrastructure, and these were important landmarks in the promotion of industrial development generally in the country. Mention should also be made of the establishment of the National Directorate of Employment (NDE) with the assistance of International Labour Organisation (ILO).

This policy of **self-reliance** continued to be pursued in the subsequent sixth NDP with a lot of emphasis on **small and medium enterprise (SME)** industries supported by the United Nations Development Programme (UNDP) and other United Nations (UN) agencies such as the ILO and United Nations Industrial Development Organisation (UNIDO). However, we must note that the political problems during this plan period (Babangida's period) as well as the much-publicized indiscipline in the banking sector had affected the attainment of expected development of

industrial growth especially of the SME industries. We need to emphasize that the thrust of developing our SME industries is intended to encourage sustainability of our industrial development. The task of our national manpower development institutions in the training of our chemical/biochemical engineers/technologists has therefore been how to relate our educational training to developing the right caliber of engineers/technologists for managing our industries including owning the industries as entrepreneurs.

Subsequent NDPs have been unclear, especially during the Abacha era. But in this democratic era, it appears emphasis is being placed on **Free Enterprise and Privatization**. It is still too early to give an unbiased assessment of this policy.

5.2 The Nigerian Bioprocess Industries: An Overview

These industries belong to the following process subsectors, viz, food, fermentation, enzyme reaction and bioextraction processes.

(a) The ***Food Process Industry*** is the most well developed out of the bioprocess industries in Nigeria. To support this fact, it is the only subsector where there are full department, i.e. Departments of Food Science and Technology or Departments of Food Technology in our Universities or Polytechnics. Examples are the Department of Food Technology of the University of Ibadan; the Department of Food Science and Technology of the O. A. U, Ile-Ife; the Department of Food Science and Technology of the University of Nigeria, Nsukka; the Department of Food Technology of the Federal Polytechnic, Bauchi; the Department of Food Technology of the Federal Polytechnic, Ilaro and finally, the Department of Food Technology of the Federal Polytechnic, Oko, Anambra State.

In a paper presented in *Nigerian Food Journal* (NIFOJ)[2] in 1984, I classified our type of food products as traditional or local foods and foreign or modern foods. This was with the aim of relating the food products to the identified process technology sources. The traditional or local foods consisted of gari, ogi, pounded yam paste, poundo-yam flour and akpu while the foreign-based foods consisted of bread, corn flakes, semovita, quaker oats and meat sausages. We should note that food beverages such as Milo or Bournvita are part of the food process industry. With such giant companies as Cadbury (Nig) Plc, Nestle (Nig) Plc, and UAC Foods in the forefront of food production, there is no doubt that this sector is well advanced technologically for certain food products. However, for locally-developed food products especially by the Federal Institute of Industrial Research, Oshodi (FIIRO), not much has been achieved in developing modern industries to take advantage of the scientifically – based processes. I must mention here the great role played by the umbrella body, the Nigerian Institute of Food Science and Technology (NIFST), which was founded in 1976 by my former Director of FIIRO, Dr. I. A. Akinrele who later became the Director CDI, ACE-EEC Lome Convention in Brussels, a great and visionary leader. I am privileged to be a Fellow of this Institute.

(b) The ***Fermentation Industry*** is the next most important of the bioprocess industries. As a part of the paper, I presented at the National Workshop on Biotechnology in Festac'77 (Durbar) Hotel, Lagos in 1993[3], I classified the fermentation industries in Nigeria into the following:

(i) Alcohol Beverage Industry:
This industry produces beer, wine and spirits.

The beer industry is a major alcohol beverage industry and is one of the first fermentation industries to be reasonably developed in Nigeria. Beer is a carbonated, weakly alcoholic beverage which is prepared from malt (barley or sorghum which has been germinated under controlled conditions); hops, water and yeast. The modern brewery technology in Nigeria can be traced back to June 12, 1949[4]. This was the day the first bottle of star beer rolled off the bottling lines of the Nigerian Brewery Limited (NBL), now Nigerian Brewery Plc. This marked the beginning of modern brewing in Nigeria. Information shows that the Federal Ministry of Industry had approved the establishment of about 52 breweries in the country as at about five years ago. We should note that the early traditional brewers in Nigeria made intoxicating liquor, known as *burukutu* or *pito* from sorghum or maize but these have not been developed into any large industry.

Fermentation industries producing wine and spirits started much later than the brewing industries in Nigeria. The Nigerian Yeast and Alcohol Manufacturing Company (NIYAMCO), Bacita, was the first commercial plant to produce pure alcohol from molasses. The company, which is not older than 35 years, produces the three grades of alcohol, namely potable, industrial and technical grade alcohols which are part of the chemical solvents associated with organic chemicals industries. Other known companies producing potable alcohol (in form of wines and spirits) include the United Distillers and Vintners (Nig) Ltd, Otta and the International Distillers also at Otta and many others. Present estimate is that the current level of alcohol production is a far cry from the national demand. What is important in any design of an alcohol plant should be its versatility to use raw materials ranging from molasses to cereal or tuber starches.

(ii) Pharmaceutical Industry:
The plants in this category concern mainly the antibiotic and hormonal drug productions. At the present time, more than 40 years after independence, our pharmaceutical plants are at best only finishing and packaging plants of imported active principles of drugs. This is very unsatisfactory and it is clear that Nigeria should now begin to produce, through fermentation industries, the various active ingredients for the pharmaceutical plants.

For many of our present plants, the finishing operations existing in the country are mixing and tabletting operations. With the colossal amount of money spent on importation of pharmaceuticals annually, it is reasonable for the country to speed up efforts at developing these plants. Primary antibiotics producing plants of importance are those producing penicillin, actinomycin, tetracycline, chloramphenicol and others of importance to our health care delivery system. The hormonal drug producing industry that should be considered include the progesterone and cortisone drugs producing plants.

(iii) Food Supplement Industry:
These are plants involved in manufacturing vitamins, amino acids, biomass protein, colourings/flavourings, acidulants and bakers' yeast. These products are used as supplements in the food industry. A common acidulant is vinegar, which is used in tenderizing and flavouring meat. There are virtually no fermentation industries producing these products in Nigeria. I am aware of research carried out by the Federal Institute of Industrial Research, Oshodi (FIIRO) in the late 60s and early 70s on the production of vinegar through the use of acetic acid bacteria on palm wine alcohol. Also, FIIRO made some attempt at research into the production of protein biomass from our industrial waste or by-products. The former Federal Ministry of

Science and Technology had in the past made some attempt at initiating, the local fabrication of a plant for bakers' yeast production.

(iv) Organic Chemicals Industry:
This industry is supposed to produce chemicals, mainly solvents such as acetone, butanol and isopropanol. Industrial or technical alcohol may also be included in this category, even though they are usually produced in plants producing potable alcohol. Apart from the alcohol industry, there is no known fermentation industry producing acetone, butanol and isopropanol as organic chemicals. One advantage of production is that chemicals from this source do not have carcinogens unlike chemicals from the petrochemicals.

(v) Commercial Enzymes Industry:
This industry produces commercial enzymes which are used in the food and beverage producing plants. Some of the important commercial enzymes are:

(a) Amylases for modification of various starches and for producing simple sugars.

(b) Lactase for removal of lactose from milk or clarification of milk.

(c) Celulase for conversion of cellulosic solids into water-soluble sugars.

(d) Pectinase for clarification of fruit juices and other beverages by controlled breakdown of polygalacturonic acid.

(e) Glucose isomerase for isomerization of glucose to fructose or invert sugar.

(f) Invertase for conversion of sucrose to fructose and glucose, and

(g) Penicillin acylase for converting Penicillin G (natural penicillin) to 6-aminopenicillanic acid (6-APA) which is the starting material for synthetic penicillins.

There does not appear to be any evidence that there are yet commercial-based industries producing these enzymes. There was an attempt by the Raw Materials Research and Development Council (RMRDC) and an Ilesha Brewing Industry to produce commercial amylase enzyme for the brewing Industries.

(vi) Biotreatment Process Industry:
These are fermentation industries where complex mixtures of solids and dissolved components in waste liquor are reduced, through fermentation, to low concentrations of these components. This category of process plants had received little or no attention nationally until the active participation of the Federal Environmental Protection Agency (FEPA) now the Federal Ministry of the Environment, which is now making manufacturing industries to set-up biotreatment plants.

A few manufacturing industries such as Cadbury Nig Plc at Ikeja and the Agbara Industries under a coordinating agency now have biotreatment plants. However, the efficiency of these plants need to be evaluated, and if necessary improved upon.

(c) The ***Enzyme Reaction Process Industry*** is one of the remaining two process industries that are still in their infancy. This industry depends on the availabilty of industrial or commercial enzymes. These enzymes can be made available through fermentation as mentioned earlier

or from bioextraction process. A typical example is the production of fructose syrups using amylases and maltase from starch materials. The alternative process is to use acid hydrolysis to produce the syrups but the quality is always far below that of using enzymes.

(d) The ***Bioextraction Process Industry*** is the last of the bioprocess industries and this is also in its infancy in development in this country. This industry involves extracts from plant and animal sources especially the plant sources. Some laboratory studies in our Universities and Research Institutes are good bases for developing process plants for bioextraction. Some examples here are papain production from *Carica papaya* (pawpaw), Dogoyaro extract (anti-malaria extract) from appropriate plant source, Lemon grass extract from lemon grass. The School of Pharmacy of OAU, Ile-Ife need to be mentioned here for their pioneering efforts in production of active principles of drugs through bioextraction processes.

5.3 Contributions To Process Biotechnology Development in Nigeria.

This is a summary of some projects which have been carried out in Nigeria in the past three decades or so and which I believe, have contributed to process biotechnology development in Nigeria.

5.3.1 Contributions from FIIRO:

I recall a project started in FIIRO in 1966 and this was in bioextraction process. The project was to produce a proteolytic enzyme, papain, from *Carica papaya* (pawpaw) on scale to replace the imported papain used in the dehairing of the leathers in the Northern part of Nigeria especially Kano. The project showed many technical aspects of industrialization with the following types of problems, *viz*, the growing of large number of pawpaw trees which had to be grown at FIIRO at the time in order to use the green fruits through its latex, the delicate,processing conditions such as temperature/time required in the dryer, and the packaging and storage of the labile enzyme. However, it was the politics of acceptance of our locally produced products that was more interesting. Having been sure that the quality of our papain matched that of the imported one (FIIRO had access to the imported products through another Federal agency, the Customs), FIIRO sent a few kilograms of the product to some leather industries in Kano for testing. The companies accepted the product and commended its quality but wanted FIIRO to send them tonnes of the product. Of course, that was not possible unless the whole of Oshodi was used to plant the pawpaw trees. The puzzling thing is that papain being a catalyst, there was no need for any large quantity. The action of the leather industries was to discourage FIIRO from any further development of the project.

FIIRO was known to use task forces to solve multidisciplinary problems. The mechanized gari production of FIIRO is an example of a *food process* which has been given wide coverage. The gari project had been on for very many years since 1956. Yet by 1966, there was still a lot to be done to bring the project up to a modern industrial project. The first indication of a completed project for the gari process came with a British patent 121547 in 1972 titled "Producing Gari from Cassava Root" authored by Akinrele, Ero and Olatunji. The typical unit operations for mechanized gari production is as shown below:

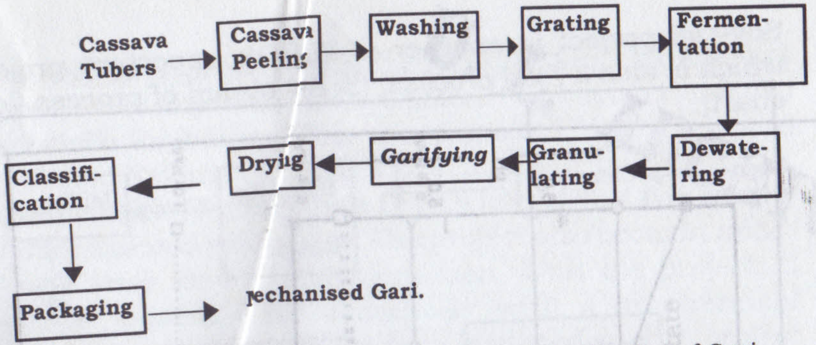

Fig. 1: Unit Operations for Mechanized Production of Gari

One highlight of work on the gari process was the use of pre-fermented seed cassava mash or liquor to accelerate the 2-stage fermentation in gari process and thus reducing fermentation time by about one-half, which in economic terms is very rewarding.

One other problem solved at FIIRO in the fermentation operation of the gari process was the process control monitoring needed to ensure that the initial organic acids formed mainly by *Corynebacterium manihot* and the subsequent esterification and ketonation by a second set of organism, *Geotrichum candida* were measurable by a simple physico-chemical model. It was shown that the total acid / pH vs. time profile in a typical batch fermentation run was adequately explained by the well-known Henderson-Hasselbalch model equation of buffers showing

$$pH = pka^1 + \log B/A$$

where B is conc. of base of buffer and A is conc. of its conjugate acid of buffer

Thus, at the stage where the pH remains unchanged with large production of total acidity is an indication that esters and ketones are being formed causing buffering and the model is suitable for use as a process control system. This led to a publication in 1974[5].

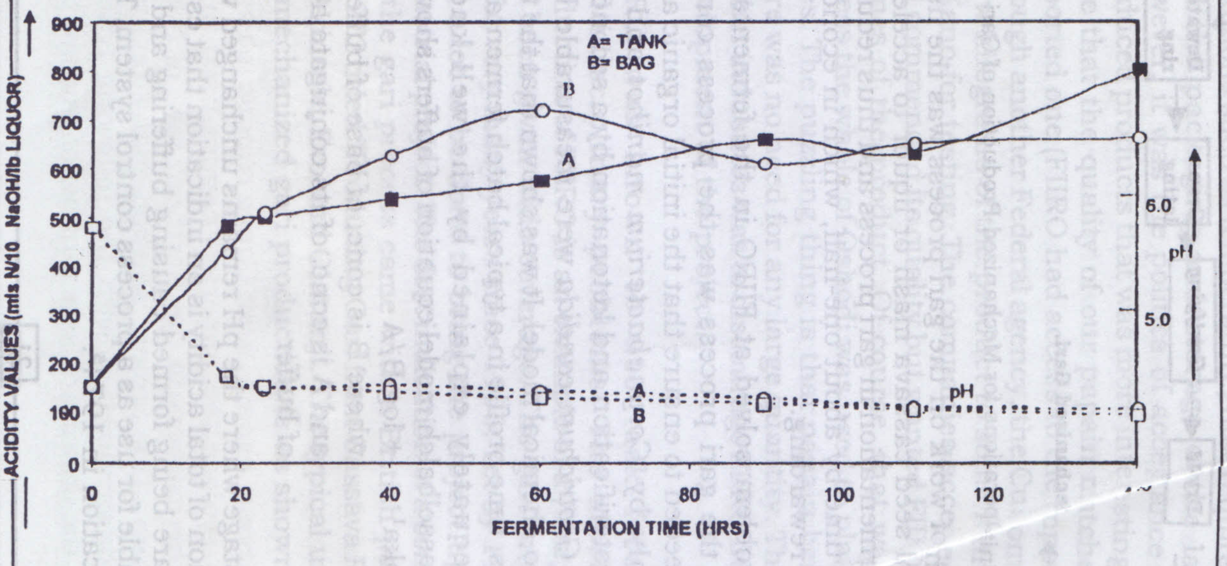

Fig. 2: Total Acidity and pH Relationship in Cassava Mash in Tank and Bag. During Fermentation

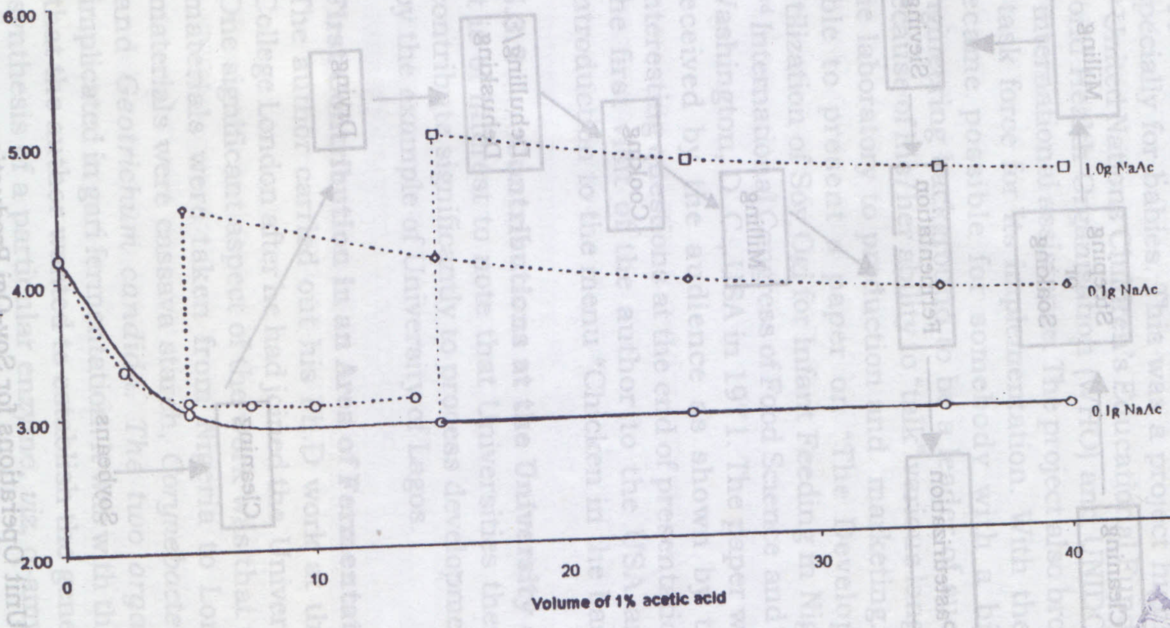

Fig.3: pH/Acidity Relationship for Acetic Acid/NaAcetate System. Initial Conc. of Acid = 0.001%

Soy-Ogi project is another of FIIRO's important project which is also a *food process*. (See diagram of process flow chart).

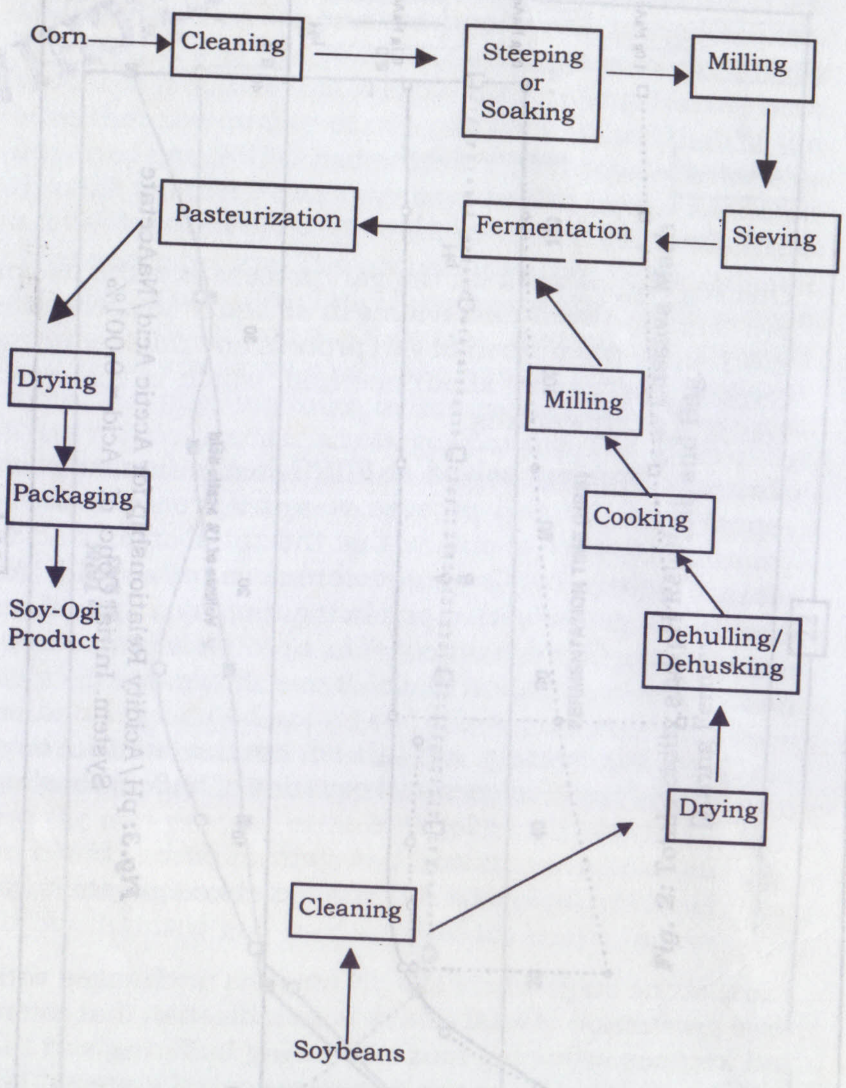

Fig. 4: Unit Operations for Soy-Ogi Production

Soy-Ogi is a protein-enriched cereal food which was supposed to improve our local protein-deficient cereal food especially for babies. This was a project highly favoured by United Nations Children's Educational Fund (UNICEF), World Health Organisation (WHO) and UNIDO as worthy of international assistance. The project also brought about a task force for its implementation. With the project, it became possible for somebody with a biochemical engineering background to be a leader of such a project because of his/her ability to "talk" various languages from the laboratory to production and marketing. FIIRO was able to present a paper on "The Development and Utilization of Soy Ogi for Infant Feeding in Nigeria" at the 3rd International Congress of Food Science and Technology, Washington, D. C., USA in 1971. The paper was very well received by the audience as shown by the various interesting questions at the end of presentation. This was the first visit of the author to the USA and his first introduction to the menu "Chicken in the basket".

5.3.2 Contributions at the University of Lagos

It is of interest to note that Universities themselves can contribute significantly to process development as shown by the example of University of Lagos.

First Contribution in an Area of Fermentation Process

The author carried out his Ph.D work at the University College London after he had joined the University of Lagos. One significant aspect of the work was that the principal materials were taken from Nigeria to London. These materials were cassava starch, *Corynebacterium manihot* and *Geotrichum candida. The two organisms were* implicated in gari fermentation. It was with these materials that the author wanted to establish the genetic control of synthesis of a particular enzyme, *viz*, α-amylase and the kinetics of synthesis of the enzyme.

The presenter's/author's Supervisor, Prof Malcolm Lilly, FRS told him that he was taking a risk bringing all the major materials from Africa for a project of London University. The author politely stuck to his guns convinced that Nigeria and indeed Africa would benefit more from these results and that was his objective. The author had a rough and tough time. After about $2^1/^2$ years of persistent work, the "Oshodi organism" as *Corynebacterium manihot* was called by the author's Supervisor, the organism showed a variation in the then well-established mechanism of synthesis control (a unique one at that) and the so-called Oshodi organism fetched the author his Ph. D with so much pride. This was a new mechanism the "Crabtree Effect" that the world of bioprocess technology had speculated on for the previous 30 years.

The centerpiece of the research work was the validity or otherwise of the famous "basic Terui's Kinetic experimental model" which had existed for many years before the work. The model is as shown below: -

$$\frac{d\varepsilon}{dt} = a\mu - b\frac{d\mu}{dt} - k\varepsilon \qquad \text{(a)}$$

where a, b, & k are model constants
ε = specific rate of enzyme formation
μ = specific growth rate
t = fermentation time

On his return to Nigeria, the author supervised a research student, Mr. F. Aberuagba (now Dr. F. Aberuagba of FUT, Minna), in this area of research in the early 80s before we ran out of any functioning equipment and materials in this field. Two journal publications[6,7] resulted from the research work.

Second Contribution in an Area of Food Process

The quality of food product is an important index in determining its price. This quality may deteriorate with storage and thus affect its price and acceptance. It is, therefore, important to have a quick and reliable method of knowing the quality of the food product in any given situation. Also, efforts made at improving preservation techniques require a quick and reliable method of assessing the efficiency of such techniques. My group in the department has worked in the past fifteen years or so in developing mathematical models of food spoilage during storage. This is to enable a quick and reliable method of predicting food quality during storage. Food products that have been studied include onions, oranges, plantains and grapefruits.

Because of the importance of the above problem, our department decided first to look at the example of onion spoilage. In 1981, the author was fortunate to be an internal examiner to a Ph. D thesis oral examination with the topic "Studies on Microbial Spoilage of Onions *(Allium cepa* L)"[8]. The candidate was Miss O. O. Oguntuyo now Dr. (Mrs.) O. O. Aboaba of the then Biological Sciences Department now of the Department of Botany and Microbiology. What was exciting and intriguing to any bioprocess engineer was the rich data available which could be used to test mathematical models in this area of research work. In 1983, one of our research students, David A. Shoyombo, took on a pioneering project on "Mathematical Modelling of Onion Spoilage During Storage". The basic thing in formulating any mathematical model are the underlying assumptions. For this work, Shoyombo made among others the following assumptions:

(i) The model follows the Michaelis-Menten enzyme reaction model.

(ii) The change in temperature due to reaction metabolism is negligible, hence the temperature effect is assumed to be constant.

(iii) Oxygen concentration is constant, hence there is no effect on the rate of reaction.

(iv) The overall effect of the food spoiling organisms is represented by the effect of *Pseudomonas fluorescens*, because its enzyme effect is the most lethal to the onion.

(v) The reaction step at which the product is formed is irreversible.

(vi) The onion self-degradation spoilage effect due to age is insignificant compared to spoilage effect due to infection within a time limit.

The basic model, the Michaelis-Menten enzyme reaction kinetics model, is given as

$$V = \frac{dP}{dt} = \frac{-dS}{dt} = \frac{V_{max}\, S}{Km + S} \quad \text{---(i)}$$

Building up the model with effects of temperature, water (Humidity), pH and enzyme inhibition, we have

$$\frac{d[P]}{dt} = \frac{-d[S]}{dt} = \frac{Ko \exp(-Ea\ /\ RT)\ [E][S]a_w}{(1 + H^+/K_1 + K_4/H^+)(1 + Km/[S])(1 + [i]/K_i)} \quad \text{----(ii)}$$

This was reported by Olatunji and Shoyombo in a paper in 1986[9]

The model equation was tested using the experimental results of Oguntuyo (1981)[8] and two relevant graphs in the work are as shown in Figures 5 and 6.

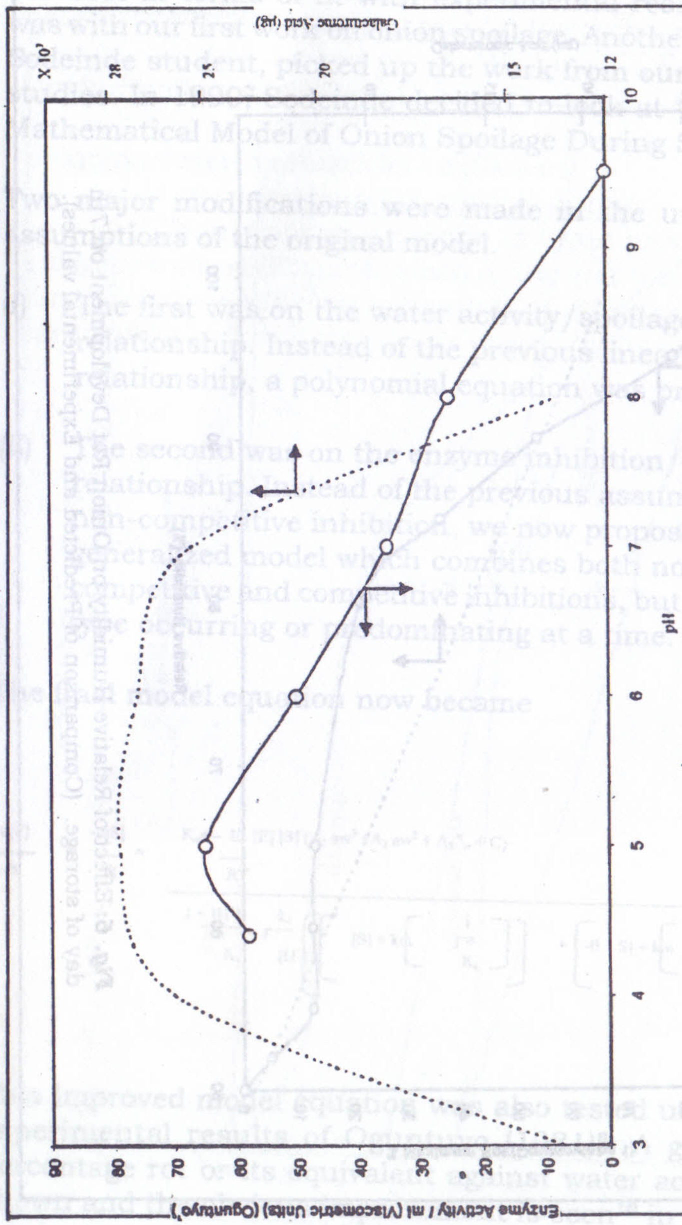

Fig. 5: Effect of pH on Activity of Pectic from *P. fluorescens* at 29 °C on 7th day of storage. (Comparison of Predicted and Experimental values).

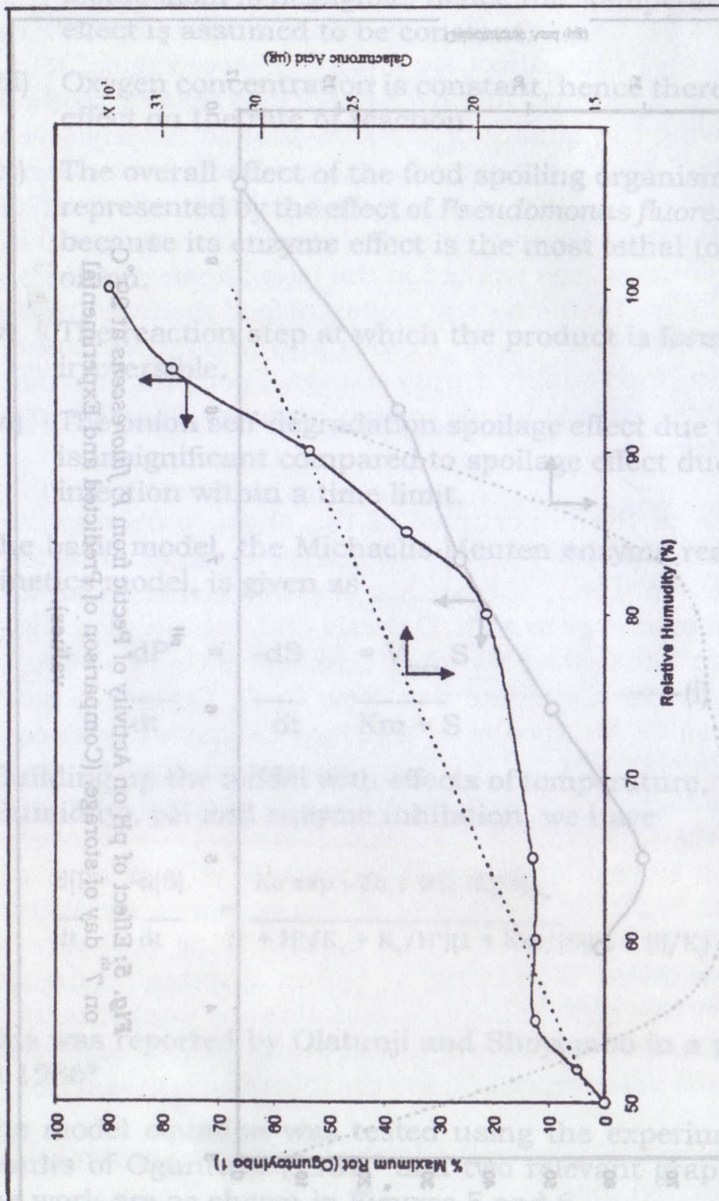

Fig. 6: Effect of Relative Humidity on Onion Rot Development on 7th day of storage. (Comparison of Predicted and Experimental values)

Like most mathematical models, the first try may never be the best in terms of fit with experimental results. So it was with our first work on onion spoilage. Another research Sodeinde student, picked up the work from our previous studies. In 1990, Sodeinde decided to look at "Improved Mathematical Model of Onion Spoilage During Storage".

Two major modifications were made in the underlying assumptions of the original model.

(i) The first was on the water activity/spoilage relationship. Instead of the previous linear relationship, a polynomial equation was proposed.

(ii) The second was on the enzyme inhibition/spoilage relationship. Instead of the previous assumption of non-competitive inhibition, we now proposed a generalized model which combines both non-competitive and competitive inhibitions, but with one type occurring or predominating at a time.

The final model equation now became

$$\frac{d[P]}{dt} = \frac{-d[S]}{dt} = \frac{K_o e^{-\frac{E_a}{RT}} [E][S](A_1 a_w^3 + A_2 a_w^2 + A_3 a_w + C)}{\frac{1+[H^+]}{K_1} + \frac{k_4}{[H^+]}\left[\left[[S] + k_m\left[1 + \frac{i}{K_i}\right]\right] + \left[-\theta\,[S] + k_m\left[1 + \frac{i}{k_i}\right]\right]\right]}$$

This improved model equation was also tested using the experimental results of Oguntuyo (1981)[8]. A graph of percentage rot or its equivalent against water activity is shown and the obvious improvement is seen[10] in Fig. 7.

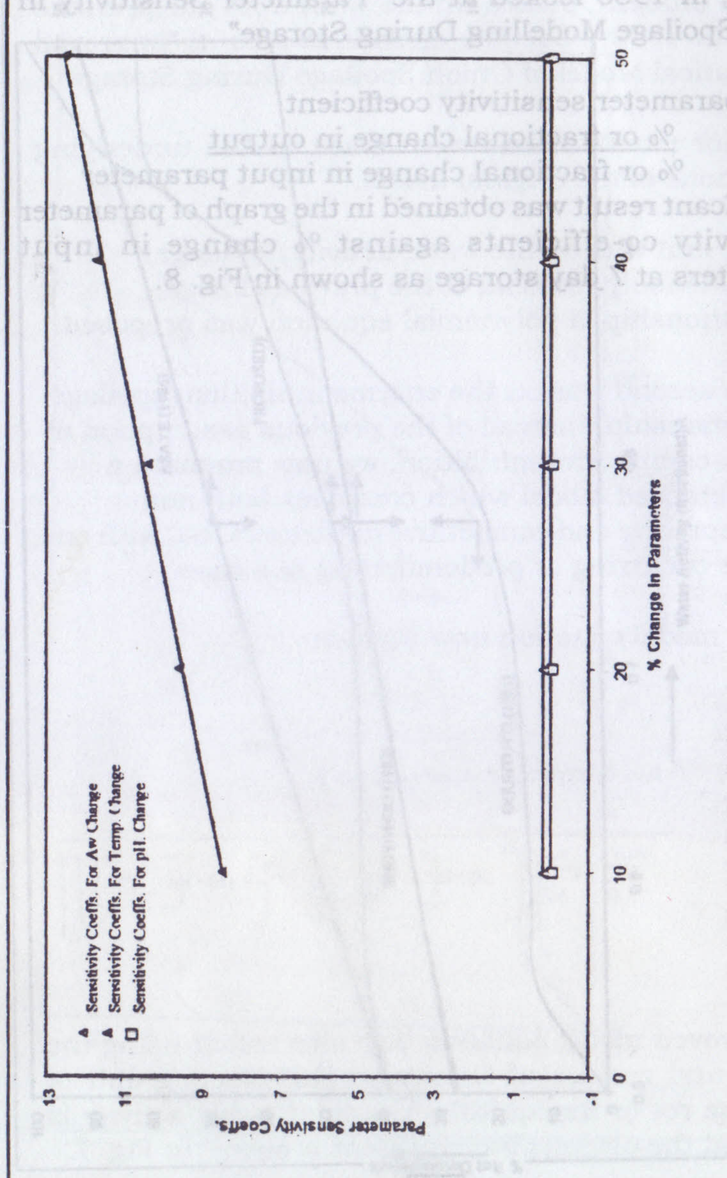

Fig. 8: Parameter sentivity co-efficients against chage in parameters at 7th day of storage

We could see that the results[11] appear to be a reflection of the exponential, linear and reciprocal forms of temperature, T; water activity, A_w; and pH factors respectively in the model equations. The temperature effect showed the greatest change. Our conclusion from the results was that great care must be taken regarding the accurate or precise measurement of temperature in particular in the use of the model.

Third Contribution in an Area of Fermentation Process

Another category of research work which has been of interest to our group in the department is Optimization studies using Factorial/Composite design technique. This has been useful in the optimization studies of the yield of alcohol from palm wine (an alcoholic beverage) or of the yield of dilute acetic acid (vinegar) from palm wine. The interest in palm wine work has arisen from the author's stay in FIIRO. Also the pioneering work by Ogboja and Okorafor[12] in 1976 on the application of factorial experimental technique on optimum yeast propagation was an inspiration to our development of work in this area.

In a classical work reported by Olatunji and Onyeneke[13], 2^4 Factorial/Composite design technique was used. Using the statistical strategy of factorial design, the effect of 4 variables, *viz*, pH (A), initial sugar concentration (B), temperature (C), and alcohol concentration (D), on the *yield of alcohol from palm wine* was studied. The pH, initial sugar concentration and temperature were found to have real effects at 5% level of significance while alcohol concentration was found to have negative effect. Also, the interactions AB, AC, CD, BD, ABC, ACD, BCD, ABD, and ABCD were found to have insignificant effects at 5% level while BC and AD have significant effect.

Finally, using a composite design, optimum values were found to be pH (5.25), initial sugar concentration (25%), temperature (34°C) and alcohol concentration (0%).

Further work in this area of our research group has used an alternative optimization technique, that is, the Box method and the result when compared with that of using composite design[14] has been encouraging especially for further studies.

6.0 INDUSTRY/ACADEMIA COOPERATION IN ACHIEVING SUSTAINABLE TECHNOLOGY DEVELOPMENT

At the World Congress of Engineering Educators and Industry Leaders held from 2nd to 5th July, 1996 in Paris, France, where I was privileged to be present, it was stated by Dr. Yakuyuki Aoshima of United Nations Educational Scientific and Cultural Organisation (UNESCO) that the General Conference of UNESCO at its 27th session in 1993 approved the (University Industry Science Partnership) UNISPAR Programme. This programme was aimed at promoting international cooperation in networking and in information dissemination as well as assisting UNESCO member States, in particular developing countries and countries with economies in transition in identifying and implementing university-industry joint projects. The main goals of the programme were;

(i) Adaptation of University Engineering Education to Industrial needs,
(ii) Continuing Engineering Education,
(iii) R & D, and
(iv) Setting up University-Industry Cooperation mechanism.

My humble contribution at this Congress was a paper on "University Engineering Education as a catalyst for Self-

Employment in Contemporary Nigeria : A Case Study"[15]. The paper mentioned the adaptation of course curricula at the Department of Chemical Engineering of the University of Lagos for promoting self-employment in our graduates. The involvement of successful entrepreneurs in our industries who are chemical engineers or chemists, as co-lecturers in the programme, as well as the publication of a popular text based on papers from working professionals in a previous workshop and in previous seminars specifically organized for that purpose were highlighted.

My other contribution in another Congress, the Global Congress on Engineering Education in Cracow, Poland between 6 – 11 September, 1998 was a presentation of a paper on "Academia/Industry Cooperation in Effective Management of the Industrial Training of Engineering Students in Nigeria : A Case Study". This paper presented by Olatunji and Aina[16] showed the large amount of data accumulated by the Central Industrial Liaison and Placement Unit of the University and the useful information that can be drawn from such data.

The paper highlighted the following:

(i) the difficulties of placement of students in appropriate industries, where there was decline in the placement of chemical engineering and civil engineering students in the recent years

(ii) problems of ensuring appropriate monitoring of students by institution-based supervisors, where results showed a preponderance of 1-visit monitoring over the desired 3-visit monitoring

(iii) the moderate pass only in the maintenance of quality in the overall performance of students during industrial training, where the majority of the students had the B grade.

I must give credit to a colleague of mine, Dr. F. A. Falade of Civil Engineering Department of this University who has initiated a process of building up, in our faculty, University/Industry cooperation with International connection. I sincerely hope that his efforts will yield good dividends for our University, the University of Lagos, especially with our proposed hosting of the 1st African Regional Conference on Engineering Education later this year.

7.0 PROCESS BIOTECHNOLOGY AND INDUSTRIAL DEVELOPMENT IN OUR NEW MILLENIUM

It is only appropriate to end the technical aspect of this discourse with what our expectations in this new millennium are. Unlike the developed countries, which have track records of achievements in many fields including process biotechnology, Nigeria has little to show for development in this field. This means that while the developed countries are looking at new horizons in this millennium, our developing countries including Nigeria must add to any new horizons the old technologies that they are yet to develop. While we must agree that it is not wise at this time to re-invent the wheel, we must note that no developed country will give off its technology without paying high price for it which may even be unaffordable to many developing countries.

A *"peep"* back at the relevant section of this paper on the Nigerian Bioprocess Industries shows many of the shortfalls waiting to be remedied.

We cannot however, ignore new horizons as identified by the United States of America, the pacesetter in this field.

In a report from the Biotechnology Research Sub-committee, the Committee on Fundamental Science and National Science and Technology Council of the U. S. A, the following priorities were identified:

(a) Agriculture:
Agricultural biotechnology offers efficient and cost effective means to produce a diverse area of novel, value-added products and tools. It has the potential to increase food production, reduce the dependency of agriculture on chemicals, and lower the cost of raw materials, all in an environmentally friendly manner.

(b) Environment:
The focus in environmental biotechnology is on bioremediation. This involves the use of living organisms or their products to degrade wastes into less toxic or non-toxic products and to concentrate and immobilize toxic elements, such as heavy metals, to minimize industrial wastes and rehabilitate areas fouled by pollutants or otherwise damaged through ecosystem mismanagement.

(c) Manufacturing/Bioprocessing:
The demand for new and improved commercial products increasingly will be met through bioprocessing, a type of advanced manufacturing that employs chemical, physical, and biological processes employed by living organisms or their cellular components. Bioprocessing can provide products with unique and highly desirable characteristics and offers new production opportunities for a wide range of items.

(d) Marine Biotechnology and Aquaculture:
Oceanic organisms constitute a major portion of the Earth's biological resources, yet most of these organisms (primarily microorganisms) are yet to be identified. Recent advances

in molecular biology, biosensor technology, aquaculture, and bioprocess engineering now promise fundamentally new approaches and opportunities for identifying, using, and managing biological resources from the seas.

All these new horizons must also be in our plan for this new millennium. How and when we are able to achieve these laudable objectives are other matters.

8.0 CONCLUSION

It is obvious that process biotechnology as a subsection of biotechnology is itself a wide discipline. It encompasses food, fermentation, enzyme and bioextraction processes. We cannot ignore the fact that the present development of process biotechnology in Nigeria is very low. That, I am sure, is not in dispute. Our policy makers must realize that biotechnology has different areas of economic targets, namely, agriculture, medicine, environment and process/ industry. Our policies must therefore be clear on which areas we are targeting our efforts especially with funding. For the development of any of our technologies, our efforts must start with our early childhood education to bring out principally the ability to visualize the different aspects of our environment in relation to the laws of nature. Therefore the development of the skill of visualizing must start very early in life for any meaningful contribution in the world of technology. This is a direct appeal to the Early Childhood Association of Nigeria (ECAN) and its current President, Dr. (Mrs.) F. Ajike Osanyin to begin to look at the introduction of rudiments of technology into their curriculum without delay.

RECOMMENDATIONS

Our nation, Nigeria, needs to do the following:

(i) Restructure our basic education at the nursery stage to the primary stage in order for our children to develop the ability to visualize problems involving natural laws. A drastic rejuvenation should be given to childhood education.

(ii) Bring out in our children the survival instinct and ability to use one's talents in a positive manner in order to cope with this survival using the forces of nature.

(iii) Remodel our present curricula to bring out balanced personalities in our secondary and tertiary educational products involving the arts, social and business sciences, and natural basic and applied sciences. In other words, a graduate in arts should be able to make modest repairs on his cars or other engineering appliances.
Also, a graduate in engineering should be able to develop himself in creative arts.

(iv) Increase the guidance and counselling efforts of our schools on our youths as to their careers in relation to their talents and personalities.

(v) Give more encouragement nationally to the development of our basic technologies rather than just importing foreign technologies or their products for local use.

(vi) Make our people identify their human, physical, and mental powers, which are God-given, in order to be able to adapt, utilize and ultimately control the physical and social environment.

(vii) Review our national policy which assumes that our economic development depends on a 60:40 ratio of science to humanities in our educational training institutions as this is a farce. Rather, even a smaller ratio of science to humanities in our educational training system with a more efficient and effective capability of trained scientists is more preferable. To complement this, we need our broad population to be knowledgeable and skilful in routine practical technology.

(viii) Create awareness in the body politic, especially by our religious bodies, about the seriousness of our national survival since it is linked with the events of our creation. This is comparable to the seriousness of "Word becoming Flesh" which is a good example for us believers in Jesus Christ. I believe that the drastic action taken by God in the incarnation of His Son, Jesus Christ, in order to have spiritual survival teaches us also of the drastic action that should be taken in our technology development if we need physical survival.

EPILOGUE

We are aware of the cry in some quarters including that of the late Chief Moshood Abiola of the need for Africa to be paid "Reparations" for the wrong done to it by our former Colonialists . But we must realize that the worst part of our colonialism and slave trade experienced by our people is not the loss or torture of the people carried away or the raw materials carted away over time but, more importantly the psychological indoctrination of our people that our traditional or local technology was no longer good and that they did not need further development because the foreign, imported technology was better or even best.

As a result, it was made clear to us that we did not require to *reinvent the wheel* and, of course, most of our policymakers and foreign-trained top academics and professionals were the mouthpiece of our neo-colonialists in this matter. This is why in almost all of our local technology relating to food, transportation, clothing, housing etc, there are large local technology development gaps which have become difficult to fill. This is what I want to call a psycho-developmental dis-equilibrium in our traditional technology development. This defect has been further encouraged or accentuated by our foreign-based education introduced by our former Colonialists. By contrast, the Chinese technology development has grown from its traditional technology. One good example in the Chinese case is their technology of acupuncture which is now adopted by Western culture after many years of rejection. In contrast our traditional medicine is regarded by the Western culture as a "no-go area" and, of course, until in the recent few years, this "no-go area" policy was accepted by our own political leaders and top administrators.

It appears clear to me that the imperatives for process biotechnology development must find solution in the equivalence between spiritual survival and physical survival. While spiritual survival for us Christians can only be achieved through "theWord becoming Flesh" and our belief in the sacrifice of God for us, physical survival, the genesis of which dates back to the sin of man in the Garden of Eden, can only be achieved by extending all our human, physical and mental powers so as to adapt, utilize and ultimately control our physical and social environment for the sustenance of life, the survival of the community and the provision of conveniences for the community.

ACKNOWLEDGEMENTS

First of all, I give glory to my Lord God for making today possible. He deserves all the praises for whatever I may have achieved in life. I always believe that whatever I do in life, I do in His name.

I like to thank my parents, late Mr. Alfred Festus Olatunji (B. Mus.) and Mrs. Comfort T. Olatunji (now 87+ years), for bringing me to the world to perform my little duties for God, my heavenly Father. My parents were the ideal couple and never once in the 23 years of my life, before death snatched away my father, did I see them quarrel. This is no exaggeration. This made a great impression on me throughout my life. I must also mention my brothers and particularly my only sister, Chief (Mrs.) Olufunke .S. Ajayi for their steadfastness in keeping the late Pa A. F. Olatunji's dream of a united family alive. I also must mention my sister's husband Chief (Dr.) A. O. Ajayi who has kept faith with my sister in their marriage for the past 36 years.

I like also to mention my early life in Zaria, where my father was Principal of St Peter's Teacher Training College, Samaru at the spot where Ahmadu Bello University is now situated. One remarkable feature of our life in Zaria was the oneness displayed by all those that associated with my father including those of the Wusasa Middle School where Papa first taught on getting to Zaria. This was truly the ideal Nigeria which unfortunately has failed to materialize in the present day Nigeria. Some of Papa's students then who made a lot of impression on me as detribalized are Gen. Dr. Yakubu Gowon (RTD), Gen. Theophilus Danjuma (RTD), Prof Adamu Baikie, Mr. M. S. Angulu, Prof F. A. Olaloku, Chief Jim Nwobodo, Chief Mojisola Akinfenwa and many others I cannot easily recall.

My secondary school days were also a period of getting mature. I cannot forget our Principal then, known as "PKC", in the person of Mr. P. H. Davis. Whichever of us went to King's College, Lagos; Federal Government College, Sokoto; Federal Government College, Warri when "P. H. D" as he was fondly called, was Principal admired his role in moulding us for leadership in Society. To the surprise of some of my classmates in K. C, I was appointed a School Prefect and House Captain (Harman's House). This really trained me in practical leadership.

I cannot forget my stay at the University of Ibadan as one of the pioneer students of Azikiwe Hall in 1963. No one would have gone through a degree course in biochemistry under our only Professor Olumbe Bassir (now late) without being impressed by the thoroughness of the Professor in his discipline. He made a lot of impression on me.

My first major place of work after my first degree was the Federal Institute of Industrial Research, Oshodi (FIIRO). The first Nigerian Director of the Institute, Dr. I. A. Akinrele, was a model in leadership. He was in fact my first mentor because of his brilliance, purposefulness, kindness, and foresightedness all molded together. It was he who suggested to me to go for a conversion course in biochemical engineering at the University College London in 1967 instead of my previous intention to go for a Master's degree course in Food Science in Leeds for which I had obtained a Commonwealth Scholarship. I owe him a lot of gratitude for his fatherly role while I was in FIIRO. FIIRO was a real home to me while I was there and I owe my pleasant stay there to other people as well including my immediate boss, Engr. O. Adeyinka and others such as Dr. A. O. Koleoso, Dr. A. K. Fasina, Dr. F. A. O. Osinowo, Dr (Mrs.) H. Solomon, Mrs. A. Kuboye and many others.

My movement from FIIRO to the University of Lagos in September 1974 as Lecturer 1 was dramatic. Another mentor of mine, Prof Ayodele Francis Ogunye, made it possible. He was another born leader who was very visionary, and extremely helpful in solving other people's personal problems. While Dr. Akinrele was not particularly happy that I was leaving FIIRO, Prof Ogunye was pleased that he was able to get the first African Biochemical Engineer to start the course of biochemical engineering at Unilag. This was at the inception of our Department of Chemical Engineering. I thank him very much for making God's will come to pass. I am pleased to have in my biochemical engineering team in my department, two great colleagues, in the persons of Prof. R. A. Bello, my present HOD and Engr. (Mrs.) A. O. Ogunbayo, both Great Ife alumni. With the trio, we have been able to lay a modest foundation for the course, both at the Undergraduate and Postgraduate levels. I sincerely wish to thank these my colleagues for their support in our modest achievement. I must also not forget some of my other colleagues in the department who have been a source of pride and joy to me as colleagues. These are Prof A. A. Susu and Prof Olu Ogboja and many others. Mention must also be made of Dr. Simeon Nwachukwu, now an Associate Prof, who was jointly supervised for his Ph. D by Prof (Mrs.) T. V. I. Akpata and myself, for being a wonderful student and now a colleague.

For my academic development, I cannot ignore the role that the University College London, Chemical Engineering Department has played in my career. I wish to acknowledge the assistance I had from Prof Malcolm D. Lilly, F. R. S, my Ph. D supervisor (now late), in orientating me properly in philosophy, learning and training. I will always be indebted to him.

I must thank, most sincerely my in-laws, the Odusinas, for the unparalleled warm regards they have always accorded me since my marriage in 1973. This has made life easier than it would otherwise have been.

Lastly, I thank my family for their love, understanding and forebearance. My children, Ayodele (a graduate in Chemical Engineering), Foluso (Economics graduate-to-be), Tolulope (Diploma, Computer Science) and my only darling daughter, Olubunmi (SS2, Queens' College, Yaba) are indeed a source of great pride to me. My wife, Adefunke, and I have both struggled together for the past 29 years. I thank her for her support.

Mr. Ag. Vice Chancellor Sir, Distinguished audience, thank you all for your attention and God bless.

REFERENCES

1. "Biotechnology in National Development". Published Proceedings of the National Workshop on Biotechnology. Ed. Boroffice R. A. Festac '77 (Durbar) Hotel, Lagos. 1993.
2. Olatunji, F. O., "Appropriate Technology in the Processing of Foods in Nigeria", NIFOJ 2 (1), 61 – 64, 1984
3. Olatunji, F. O., "Industrial Typing of Microorganisms and the Development of Fermentation Industries in Nigeria", Published Proceedings of the National Workshop on Biotechnology, Ed Boroffice, R. A, Festac '77 (Durbar) Hotel, Lagos, 183 – 193, 1993.
4. "Beer Brewing in Nigeria", Report of National Office of Industrial Property (NOIP) (now NOTAP). A Comprehensive Survey of Technologies in Nigeria's Manufacturing Sector, Agro-based sub-sector. Volume 1, 52 – 74, 1985.
5. Olatunji, F. O., "A Physico-chemical model for Mixed-Culture Cassava Fermentation" Published Proceedings of the NSChE Symposium, University of Ife, Ile-Ife, Nigeria, pp 37 – 45, 1974
6. Olatunji, F. O. and Aberuagba, F., "Kinetics of Synthesis of α-Amylase in a Gari – Fermenting Bacterium, *Bacillus subtilis*", JNSChE 5(2), 7 – 16, 1986.

7. Olatunji, F. O. and Aberuagba, F., "Effects of Temperature and pH on the Kinetics of Synthesis of Activity of á -Amylase from a Gari – Fermenting Bacterium, Bacillus subtilis", JNSChE 5 (2), 17 - 20, 1986.

8. Oguntuyo, O. O., "Studies on Microbial Spoilage of Onions (Allium cepa L)", Ph. D Thesis, University of Lagos, 1981.

9. Olatunji, F.O. and Shoyombo, D. A., "Mathematical Modelling of Onion Spoilage During Storage", JNSChE 5 (1), 19 - 24, 1986.

10. Olatunji, F. O. and Sodeinde, O. A., "Improved Mathematical Model for Onion Spoilage during Storage", JER 6 (1), 1 - 11, 1998.

11. Olatunji, F. O. and Asaye, M. B. K., "Parameter Sensitivity in Onion Spoilage Modelling During Storage", JNSChE 6 (2), 147 – 152, 1987

12. Ogboja, O. and Okorafor, C. O. "Conditions for Optimum Yeast Propagation - Application of Factorial Experiment Technique", JNSChE 1 (1), 59 - 68, 1982.

13. Olatunji, F. O. and Onyeneke, A. C., "Optimisation of the Yield of Alcohol from Palm-wine using a 2^4 Factorial / Composite Design Technique", JER 6 (2), 19 -36, 1998.

14. Inwenjora, A. A., "Comparative Studies of the Box Method and the Composite Method of Optimization Integrated with the Factorial Design in the Optimisation Integrated with the

Factorial Design in the Optimisation of the yield of Vinegar from Palm wine", B.Sc Research Report, University of Lagos, 2000

15. Olatunji, F. O., "University Engineering Education as a Catalyst for Self - Employment in Contemporary Nigeria: A Case Study." "Published Proceedings of the World Congress of Engineering Educators and Industry Leaders, UNESCO, Paris Vol III, 65 -74, 1996.

16. Olatunji, F. O. and Aina, S. A. O., "Academia / Industry Cooperation in Effective Management of the Industrial Training of Engineering Students in Nigeria: A Case Study", Published Proceedings of the Global Congress on Engineering Education, Cracow, Poland, 519 - 522, 1998

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