OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, NIGERIA.

Inaugural Lecture Series 191

"FROM SCIENCE TO TECHNOLOGY & INNOVATION MANAGEMENT"

By

Professor M. O. Ilori
Professor of Technology Management

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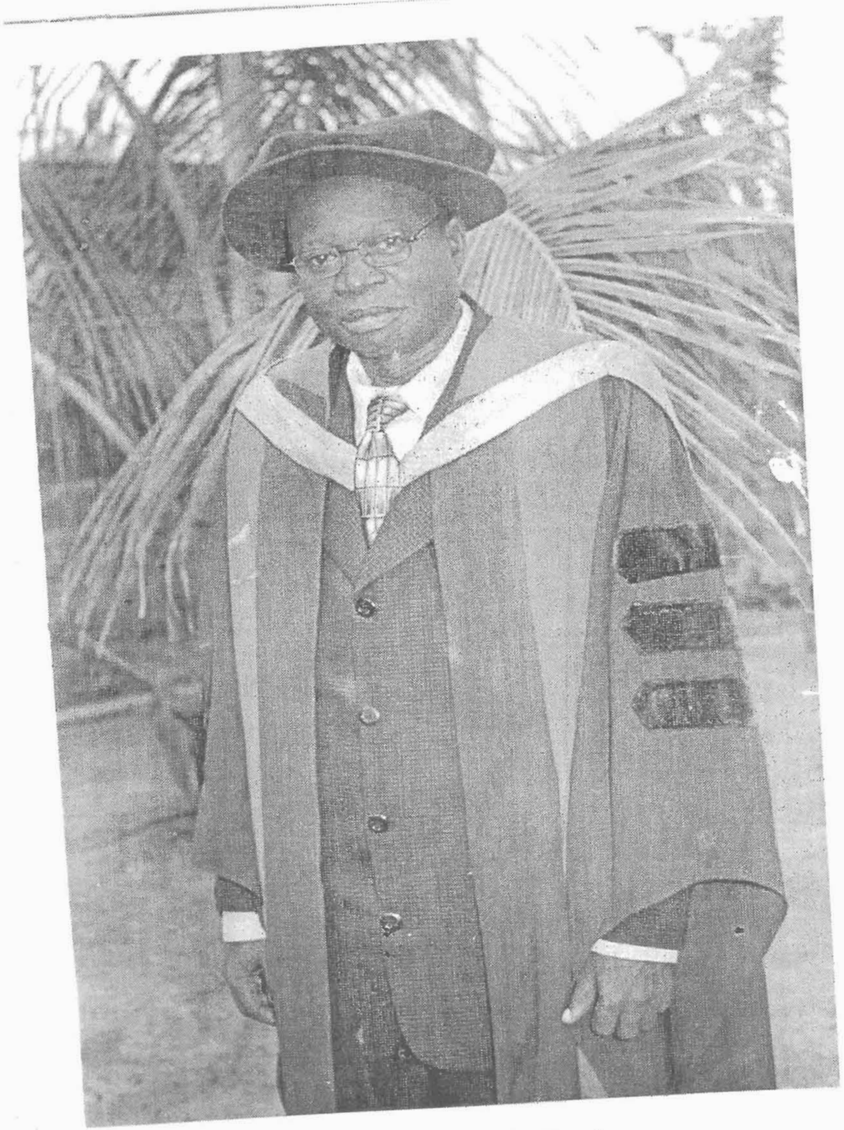

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FROM SCIENCE TO TECHNOLOGY AND INNOVATION MANAGEMENT

PREAMBLE

Mr. Vice Chancellor Sir, the Principal Officers, colleagues, visitors, students, friends, ladies and gentlemen; just of recent, I visited a friend, Architect Niyi Kehinde, who was my classmate at Baptist College, Iwo, now the site of Bowen University. After receiving me very warmly, he said he had a souvenir which would interest me and that he would only show me if I was ready to pay for it. He later showed me the souvenir which was a picture we took in 1971 when I was designated a Professor of Chemistry, University of Lagado. Those who attended the college will recollect that it was compulsory for new entrants into the College to take an entrance examination into the University as part of the orientation programme.

In the final year class, the best student in each subject was usually designated as Professor who would set questions on that subject. After leaving the College, I could only gain admission into Adeyemi College of Education, Ondo, and everybody thought the Professor of Chemistry, University of Lagado had derailed but then I came to Ife – the Great Ife, to bag my B.Sc (Hons) in Chemistry. My B.Sc. project titled 'The Electrical Conductance of Some Molten Carboxylate Mixtures' was published (Adeosun *et al* 1980). This probably marked my turning point into academics and I wish Dr. Adeosun of blessed memory was here today to listen to this lecture. I later had M.Sc. and Ph.D in Food Science and Technology. I joined the Technology Planning and Development Unit in 1982. After completing the M. Sc. and before I registered for the Ph.D, I audited many courses in the Departments of Economics and Agricultural Economics of this University. During the Ph.D. programme, I also took almost all the courses required for the M.Sc. programme in Industrial Engineering, at the University of Ibadan, and I rose through the ranks to be the first Professor of Technology Management of Obafemi Awolowo University, Ile-Ife in 1999.

This is a treatise on my academic pursuit which a friend, Professor S.R.A. Adewusi, has described as an adventure **"From Science to Technology and Innovation Management"** which incidentally has become the title of this inaugural lecture.

SCIENCE AND TECHNOLOGY

Science, an interconnected series of concepts and conceptual schemes, developed as a result of experimentation and observation, is interlinked with technology. Knowledge generated from science may be used as an input for its further development, and possibly for the development of knowledge directly applicable to economic and social goals. Science could therefore provide a starting point for technological effort or, simply put, technology may take its root from science. The development of science on the other hand depends on technology.

Technology is categorized as a special resource, an important strategy for the exploration of the natural resources sector, and an agent of social and economic change (Drucker, 1970). Technology is also described as a body of knowledge which is used scientifically by a given society at a given moment to resolve concrete problems in accordance with culture and scale of value (OECD, 1991). It is also described as systematic knowledge for the manufacture of a product, for the application of a process or for rendering of a service, including any integrally associated managerial and marketing techniques.

Technology could be embodied in tangible products such as machinery or an industrial complex, or in legal documents such as patents, licenses or know-how contracts. It may even be expressed in the form of a skill, a practice or technology culture which may be so diffused that it becomes unnoticeable in the society on which the effective operation of any technical system may depend.

Technology Management is a body of knowledge linking science, engineering, technology and social sciences as well as management for the purpose of building technological capabilities required for running an organisation in order to achieve its strategic objectives and goals. The organisation could be a public or private concern, a nation, a continent or the world as a whole.

THE INNOVATION PROCESS

Technological innovation is the first commercial introduction of a new technology, which may take the form of a product, process or service. Its emergence is as a result of several activities spanning a length of time, depending on the type of technology. The phases identified by Stanton *et al* (1994), are idea generation, screening of ideas, research and development (R&D), business analysis, prototype development, test marketing, and commercialization.

Idea generation involves a search for new ideas by such means as brainstorming, attribute listing and need identification. Ideas normally originate from the R&D organization/department, and from specific market needs. These two sources of new technology ideas have in recent years been described as technology push and market pull respectively. Whatever the source of the ideas, screening entails evaluating all the ideas with a view to identifying and concentrating on those with greater potential for success.

During the R&D phase, the idea on paper is translated into a physical product, process or service (Norris and Vaizey, 1973). The essence of business analysis is to identify product features, estimate market demand and product profitability, and assign responsibilities for a further study of the product feasibility. At the prototype stage, the laboratory output is scaled up and produced at pilot plant stage (Valentas *et. al.*, 1990)

At the commercialization stage, full-scale production and marketing programmes are perfected and the product is launched into the market. After launch, the product enters its life cycle, and the external competitive environment becomes a major determinant of its survival. These seven stages have been classified into three phases as pure research, technology development and production and marketing (Fig 1).

The seven stages or three phases in the innovation process have been presented as a step-by-step approach, which proceeds in a linear and static manner, with a phase commencing after a preceding phase has been completed. Takeuchi and Nonaka, (1986), however, suggest that a holistic or 'rugby' approach is integrative, overlapping and more appropriate in a fiercely competitive business environment where speed and flexibility are critical success factors for an innovation (Fig. 1 Model B&C). As one moves from pure research to technology development and then to production and marketing, unanticipated problems may arise that require research for their solutions. The 'rugby' approach has found wide applications in the United States and Japan where multinational companies have successfully utilized the same. Ilori *et al.*, (2000) reported that some food companies that followed all the seven phases in an integrative and overlapping manner described above in the development of new products succeeded in their commercialization efforts in Nigeria.

The innovation process requires considerable communication among different actors and institutions who act as agents of innovation. Within the boundaries of a nation they constitute the elements of a national innovation system with identifiable national and societal specificities.

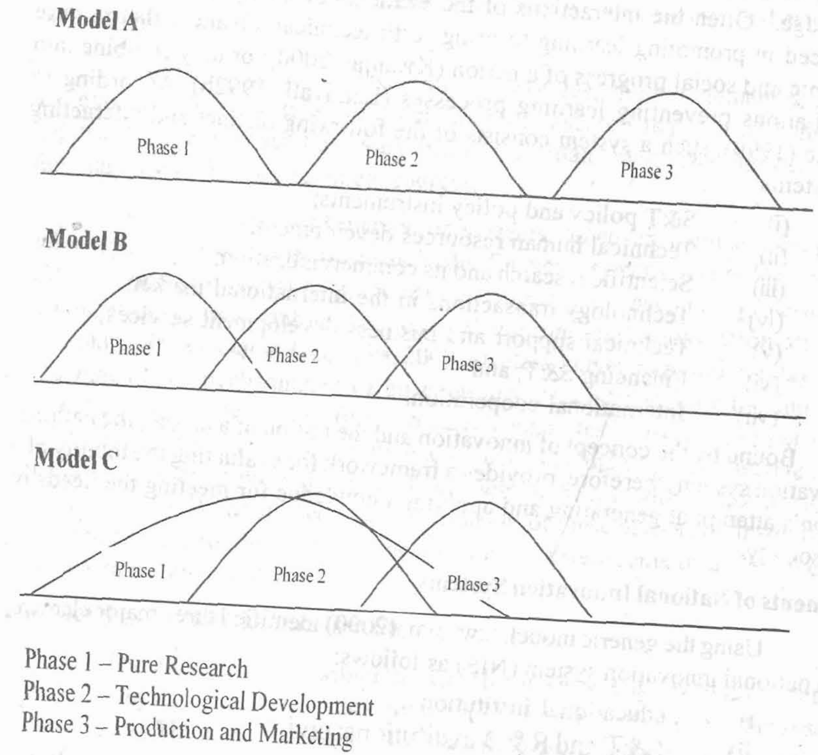

Fig. 1: Models of Science and Technology (S&T) Development for Industrial Production.

NATIONAL INNOVATION SYSTEM (NIS)

Concept of National Innovation System

The National Innovation System (NIS) has been defined in different ways by various authors depending on the theoretical approach adopted. Freeman (1987), defined it as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies." This definition emphasizes the interaction between the production system and the process of innovation.

The NIS is also described as being constituted by elements and relationships, located within or rooted inside the borders of a nation state, which interact in the production, diffusion and use of new and economically useful knowledge. Often the interactions of the elements of the system are mutually reinforced in promoting learning to bring forth technical advances that nurture economic and social progress of a nation (Kwanjai, 2000), or may combine into constellations preventing learning processes (Lundvall, 1992b). According to Lalkaka (1999), such a system consists of the following distinct and interacting subsystems:

(i) S&T policy and policy instruments;
(ii) Technical human resources development;
(iii) Scientific research and its commercialization;
(iv) Technology transactions in the international market;
(v) Technical support and business development services;
(vi) Financing S&T; and
(vii) International cooperation.

Bound by the concept of innovation and the notion of a nation, the national innovation system, therefore, provides a framework for evaluating the totality of a nation's attempt at generating and applying knowledge for meeting the needs of her society.

Elements of National Innovation Systems

Using the generic model, Kwanjai, (2000) identified three major elements of a national innovation system (NIS) as follows:

i) educational institutions;
ii) S&T and R&D institutions; and
iii) firms and industries.

Higher Educational Institutions, particularly universities, perform the traditional functions of teaching and talent filtering by which new generations of scientists, technologists and engineers are trained. They also have a social and statutory responsibility to participate in the generation of new knowledge through research and development activities which can be channeled and diffused by new ventures. A good number of technology-based spin-offs in some regions in Europe and USA have emerged directly from academic research activities of universities. The pursuance of these functions has led to the emergence of

new fields of Science, processes and major new generic technologies of wide industrial and social significance (OECD, 1998).

The modern University also plays a more active role in consulting, community services, specialized training and distance learning (Lalkaka, 1999). These are in response to the capacity building requirements of the global economic shift from resource endowments and factor costs to information- and experience-based knowledge.

Public research and development institutes, another element of the NIS, are expected to undertake different lines of research that are of commercial applicability. These institutes vary in their mandates and sizes but derive their funding mainly from government sources.

A current model of innovation systems, however, include at least some other types of actors (Fig. 6), namely the financial system, technology brokers, industry and professional associations , the legal base, non-governmental organisations, press, public opinion and international cooperation structures (Plonski, 2000, Oyelaran-Oyeyinka, 2002, Oyelaran-Oyeyinka, and Barclay, 2003). The innovative performance of an economy depends on how the individual institutions and actors (e.g. firms, research institutes, universities) perform in isolation and how they interact with each other as elements of a collective system of knowledge creation and use, and on their interplay with social institutions (OECD, 1999). Without adequate development of these actors and institutions in the domestic and regional settings the innovation system remains underdeveloped and anaemic (Juma *et al,* 2005)

Partnerships within the National Innovation System

The need and the continuous search for knowledge within the national innovation system result in the development of partnerships between the system's major actors. These partnerships cut across the public and private sectors. They are often facilitated and stimulated by the government and are defined by a joint contribution of financial research, human and infrastructural resources either directly or in kind. The partnerships within the national innovation system according to the types and characteristics of the actors are as follows (Cervantes, 1999):

(i) University-industry partnerships;
(ii) Government-industry partnership;
(iii) Research institute-industry partnerships; and
(iv) Any combination of (i), (ii) and (iii).

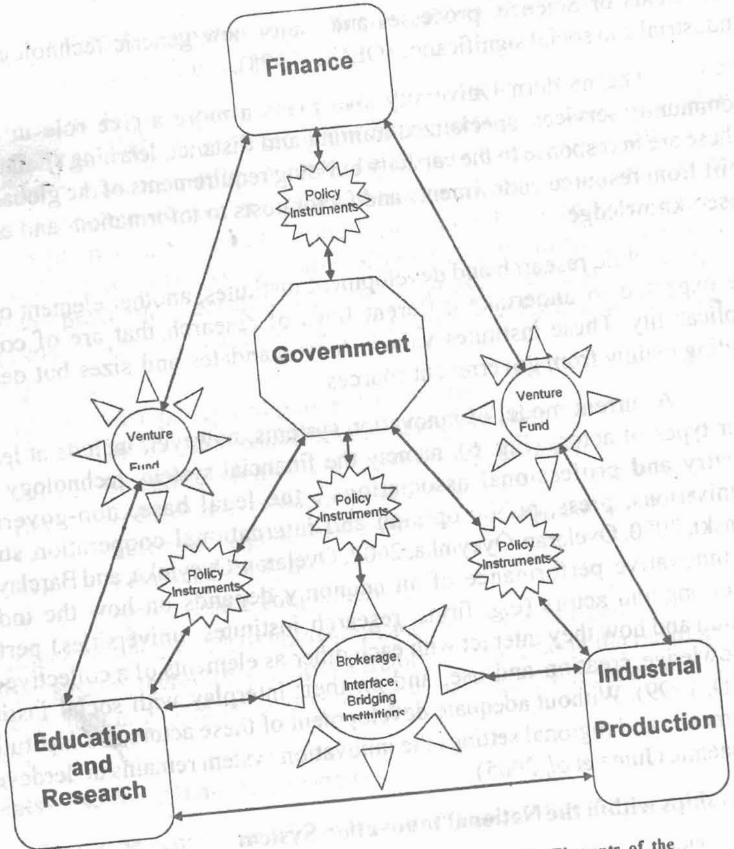

Figure 2: **Typical Structure of Interactions among the Elements of the National Innovation System**

Source: **Adapted from Tiffin (1997)**

The University-industry partnerships are spurred largely by the need for universities to look for additional sources of funds and industry's need to access a broader science base for coping with the challenges of competition. Governments' inability to sustain previous growth rates in expenditure on university research has made these institutions more adventurous in seeking stronger linkages with industry (Senker and Senker, 1997). This is reinforced by firms' willingness to take advantage of institutional innovations which are favourable to the introduction and diffusion of new technologies.

Governments go into partnerships with industry generally to reduce the technical risks associated with industrial research projects. They also induce firms to bear the remaining commercial risks that can be managed with their market strategies. This type of partnership may take the form of a joint contribution towards building infrastructure for cooperative R& D or the execution of extramural research between government agency and firms. Universities may, on some occasions, be involved in such an arrangement.

According to Cervantes (1999), industry partnerships with research institutes are more common than those with universities in developed countries and have served as vehicles for meeting specific industry needs. Most of them started as collaboration with large firms, but the increasing prominence of small and medium-sized enterprises (SMEs) in their national economies has shifted focus to linkages involving groups of small firms and research providers.

Technical collaboration among firms was reported to positively correlate with improved innovative performance in most industrial sectors, particularly in the skill to identify and adapt useful technology (OECD, 1997). Such collaboration is usually referred to technology-based strategic alliance. This occurs where the R&D project is extremely costly and is beyond the ability of any firm to fund it out of its own resources (Twiss, 1990).

The Nigerian Innovation System

The Nigerian innovation system, like any other NIS, consists of three major elements;

(i) educational institutions;

(ii) research institutes: and

(iii) industrial production by firms

These entities perform diverse but inter-related functions within public policy, legal and financial frameworks of the economy. The functions of the educational and research institutes, mostly owned by government, are as stated in the different government statutes establishing them. Industrial production organizations, on the other hand, are made up of public and private sector firms operating in different sectors of the economy such as manufacturing, mining, energy, construction, transportation and communication.

Educational Institutions:

Education, in Nigeria, is based on a 9-3-4 system with some emphasis on science and introductory technology education at the primary and secondary levels. The enrolment targets for science-based courses and non-science courses are in the ratio of 70:30 for universities and 80:20 for polytechnics. However, actual enrolment figures have consistently skewed in favour of non-science courses (Okebukola, 2002).

Nigeria's higher education sector currently has about 47 Universities, 43 Polytechnics/Colleges of Technology and several colleges of education and monotechnics. These institutions, mostly owned by the Federal and State Governments, train students in diverse disciplines such as the humanities, science and engineering to meet the nation's human resources needs. Of recent, this sector has witnessed some private sector participation with the approval and take-off of over 30 private Universities and Polytechnics. The National Policy on Education explicitly emphasizes that universities must develop the physical and intellectual capabilities of individuals and serve as an instrument of change by bringing the fruits of the nation's cultural heritage and modern technology to as many Nigerians as possible (Federal Government of Nigeria, 1981).

In addition to these functions, lecturers in these institutions, particularly Universities, conduct basic or applied research which is used primarily for their career progression. Hence, the results of such research efforts usually end up as publications in journals without commercialization by industry. These research activities are funded largely by the Government through supervisory agencies such as the National Universities Commission (NUC). This public mode of funding has closely tied the level of research activities in the higher education sector to the fluctuating fortunes of the economy (Federal Ministry of Education, 2003).

Government's funding of education, over the years, has been considered inadequate. In a Ph. D. work, which I supervised just of recent, we also found that, public funding of education averaged a paltry 4.28% of total government expenditure for a ten-year period (1990-2000). Up till 1999, funding was well below 26% of Gross Domestic Product (GDP) recommended by UNESCO. Even then, over 70% of the allocation was expended on salaries and other personnel emoluments. According to ASUU, UNESCO standard had never been met in any African country! The skewness of the enrolment in tertiary educational institutions in favour of non-science/technology disciplines showed that the meagre resources available were not channelled towards technological capability building (Oke, 2005).

The relative number of S&T personnel nationwide is very low compared with other countries. Within the Nigerian Innovation System, the Universities have the highest concentration of high quality research personnel (80.7% of research staffers). Among Polytechnics, only 2.2% of research/teaching personnel have doctorate degrees as against 27.3% found among public research institutes (Oke, 2005).

Research Institutes:

Presently, there are about 30 R&D institutes widely located across the country and operating under the supervision of their respective Ministries.

In our recent study, we found that Government's funding of these research institutes has been very poor. Between 1985 and 2000, this averaged only 0.08% of the Gross National Product (GNP), a far cry from the UNESCO recommended target of 1.0%. In spite of this low level of funding, most of these funds are expended on the running of the supervisory ministry and the administrative machinery of these institutes with very little left for the direct funding of R&D projects (Oke, 2005, Oduola *et al*, 2005 b,c).

The mandates of public research institutes were very broad in coverage but the levels of mandate achievement were on the average. Generally, R&D facilities in educational institutions and public research institutes are in very poor States but facilities in industries are better (Oke, 2005, Oduola *et al*, 2005a). The distribution of these research institutes by function reveals an over-concentration of research efforts on agricultural and medical related activities to the utter neglect of core technology and engineering ones (Oduola *et al*, 2005 and Oke, 2005). This indicates Government's priority in the National Science and Technology policy focus. Also, virtually all these research institutes, universities and other higher institutions operate outside industrial structures and conduct research that are of less relevance to manufacturing firms. The producer-user relationship, as determined by the proportion of commercialisable research findings actually commercialised, is very weak (Oyewale, 2003, Oke, 2005)

Industrial Production:

The Nigerian manufacturing industrial sector is made up of ten sub-sectors. These are:

(a) Food, beverages and tobacco;

(b) Chemical and pharmaceuticals;

(c) Textile, wearing apparels and leather;

(d) Wood and wood products;

(e) Plastic and rubber products;

(f) Pulp, paper and paper products, printing and publishing;

(g) Basic metal, iron and steel;

(h) Electrical and electronics;

(i) Non-metallic mineral products; and

(j) Motor vehicle and miscellaneous assembly.

Firms operating in these sub-sectors vary in size, number of employees, turnover and ownership with most of them operating on a small scale. According to NISER (1998), they are located across the six industrial groupings but their activities are concentrated in major urban centres. For instance, the firms along the Lagos-Ota-Ibadan axis alone account for about 44% of the total registered number of firms and roughly 52% of the employment in the manufacturing sector (World Bank, 2002). As a major employer in the Nigerian economy, the manufacturing sector had over the years, intensified training as a way of upgrading the technological capabilities of their employees. These efforts had largely resulted in the gradual decline of expatriate staff in the industry (NISER, 1996). However, we found that the technological skill intensity (0.07%) of employees which measures the ability of firms to generate and/or adopt new product and process technologies, is generally low (Oke, 2005). We also found that the Nigerian economy in the 1990-2000 period ranked fifth behind South Africa, Egypt, Algeria and Morocco in that order. The average GDP growth rate of 2.4% was rather too low. Though the industrial value added was relatively high (1.7%), the growth rate was also very low during the same period (Oke, 2005).

In our earlier study (Ilori *et al*, 2002), we found that there was a negative growth in manufacturing production between 1992 and 1995 and only a slight growth in 1996 and 1997 (Fig. 3). The rate of growth over the 1997-1999 periods was 0.3% which was below the target for the sub-sector in the National Rolling Plan. The lull in manufacturing activities within 1989 and 1997, and the inability to attain the growth targets were attributed to technological and economic factors as well as political instability. Only Oil exports largely accounted for Nigeria's survival in that period (Ilori *et al*, 2002). However, frameworks for developing technology strategies that will lead Nigeria from a natural resource based to manufacturing – based economy have been proposed (Ilori and Sanni, 1994, Ilori *et al*, 2002).

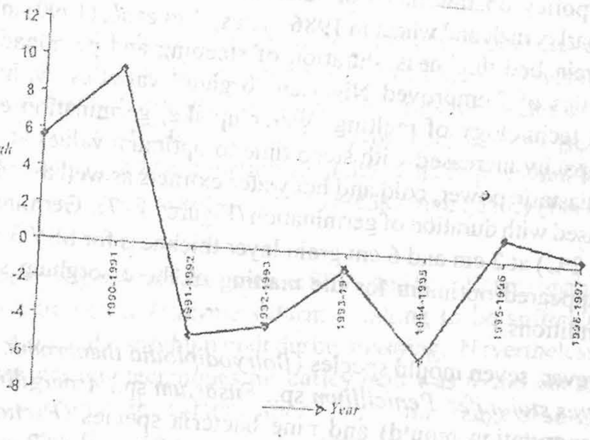

Fig 3: Growth in Manufacturing in Nigeria (base year figure of 1985=100% Source Ilori *et al*, 2002

MY CONTRIBUTIONS TO THE NIGERIAN INNOVATION SYSTEM

Mr. Vice Chancellor, Sir, as mentioned earlier, I was employed in the Technology Planning and Development Unit – which is essentially a research oriented unit and therefore one of the elements of the Nigerian Innovation System. This great University -"Great Ife" has given me a unique opportunity to do research for my Ph.D degree in an applied field before gradually moving towards technology policy, planning and development. It therefore gives me great pleasure to review my modest contributions in this vast axis spanning applied research to technology and innovation management research.

Let me pick the gauntlet dropped by a friend and research collaborator (Prof. S.R.A. Adewusi) in his inaugural lecture **"New Old Foods"**. He asked me to do justice to the development of Sorghur Malting and Brewing Technology, here we go!

Sorghum Malting and Brewing Technology

Sorghum is an important cereal crop, which ranks fifth in terms of world cereal production. It is widely cultivated in Nigeria for human consumption. It is also used to prepare traditional alcoholic and non-alcoholic beverages (Ogundiwin, *et al.*, 1998). Our research efforts in sorghum malting and brewing were in response to government policy on raw material substitution which placed a ban on the importation of barley malt and wheat in 1986. Thus, Ilori *et al.*, (1990) investigated the effect of grain bed thickness, duration of steeping and germination on the malting properties of 7 improved Nigerian sorghum varieties, with a view to optimizing the technology of malting. Water uptake, germination energy and germination capacity increased with steep time to optimum values at 18 h steep. Malting loss, diastatic power, cold and hot water extracts as well as soluble sugar contents increased with duration of germination (Figures 4 - 7). Germination for 96 to 108 h (28 ± 2°C) at 2 cm and 6 cm grain layer thickness for SSV 3 and SSV12 respectively appeared optimum for the malting of these sorghum seeds under laboratory conditions.

However, seven mould species (*Botryodiplodia theobrome, Aspergillus flavus, Rhizopus stolonifer, Penicillium* sp., *Fusarium* sp., *Aspergillus niger* and a whitish unsporulating mould) and nine bacteria species (*Escherichia coli, Enterobacter cloacae, Pseudomonas aeruginosa Sarcina* sp., *Bacillus cereus, Klebsiella aerogenes Lactobacillus* sp. *Staph. aureus)* were isolated from the sorghum varieties while malting. Some of the micro-organisms also reoccurred in the malted grains. None of them withstood the conditions of work-cooking; but, some reoccurred in the unpasteurised beer probably due to contamination (Ilori *et al*, 1991a). Though some of these micro-organisms are known to be amylolytic, their presence during malting may not be desirable since they produce toxic metabolites which could pass on to the beer during processing and produce beer gushing or render the product unsafe for consumption (Flannigan *et al.*, 1982). Hence, chemical treatments of the grain to prevent microbial contaminations during malting were also investigated. We therefore treated sorghum grains during steeping and germination with sorbic acid, sodium benzoate, nisin, formaldehyde, lime and bitter leaf extract and found that only formaldehyde, lime and bitter leaf extract prevented mould and bacterial growth at 500, 2,000 ppm and 30 mg/ml steep water respectively. None of the treatments adversely affected the malting properties of sorghum grain. In addition to inhibition of microbial growth, formaldehyde at 300 – 1000 ppm also eliminated dormancy and reduced malting loss in sorghum (Ilori & Akingbala, 1991). This makes treatment with formaldehyde a good innovation in sorghum malting.

In an attempt to reduce the high malting loss characteristic of sorghum, the effect of ammonia treatment as steep liquor on two Nigerian sorghum varieties was investigated. Steeping the kernels in 0.1N ammonia for 0 to 18 h reduced the malting loses. However, mouldiness was not prevented. And in addition, enzyme development, and other desirable properties of the grain were significantly reduced by the treatment. Malting with ammonia may therefore be useful for minimizing malting loss at the expense of optimum development of hydrolytic enzymes, provided

the malt produced will only provide malt flavour in beer and external enzymes will be used during processing. (Ilori and Adewusi, 1991)

Physical attempts were made to correlate properties of the Nigerian sorghum varieties with the malting properties of the grains. These malting properties which include malting loss, diastatic power, hot and cold water extracts as well as total sugar did not correlate with physical properties such as grain size, texture, germination energy, and germination capacity. This implies that kernels physical properties only cannot be used as indices to predict malt quality (Ilori and Akingbala, 1991b).

Some Sorghum varieties such as SSV3 and SSV12 are capable of developing enough diastatic power (enzymes) during malting to be sufficient for the self-saccharification of the sorghum malt during mashing. Nevertheless, the use of the conventional mashing techniques for barley malt was found not to be applicable for sorghum malt since the gelatinization temperature range of sorghum starch (68 to 77°C) is higher than the optimum temperature (60 – 64°C) for alpha and beta amylases. We therefore established a sorghum malt mashing procedure as shown in Fig. 8 (Ilori 1991, Ilori *et al.*, 1991b).

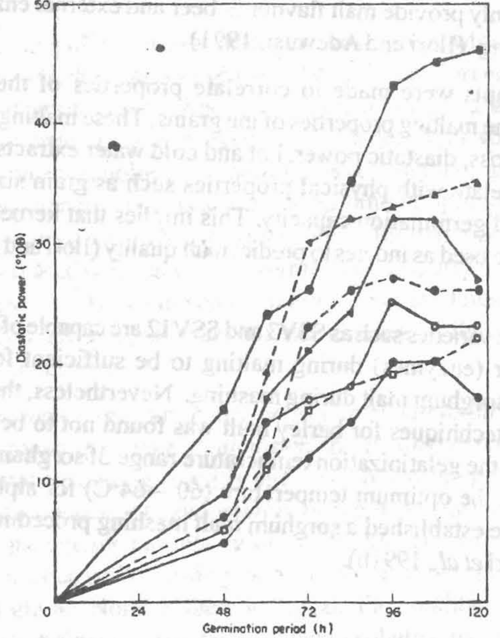

Fig. 4 Diastatic powers of sorghum malt at various germination periods. ■——■, SSV3; △---△, SSV12; ▲——▲, SSV7; ●---●, FFBL; ○——○, MORI; □---□, KSV4; ●——●, KSV8

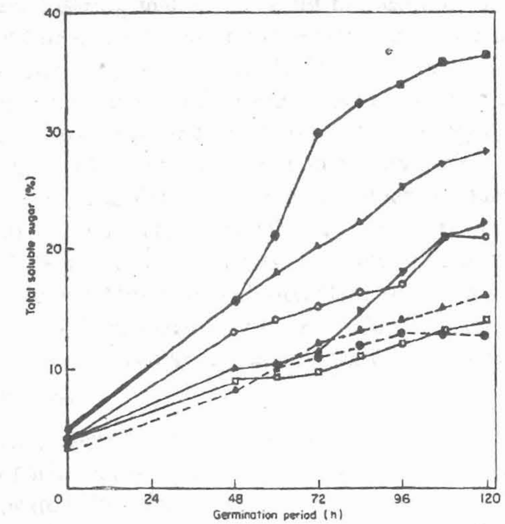

Fig. 5 Total soluble sugars of sorghum malts at various germination periods. ■——■, SSV3; △——△, SSV12; ▲——▲, FFBL; ○——○, MORI; ▲---▲SSV7; ●---●, KSV8; □——□, KSV4

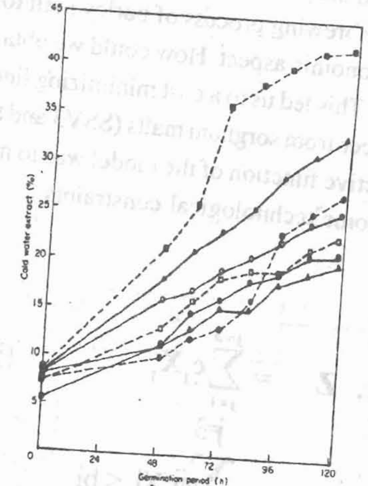

Fig. 6 Cold water extracts of sorghum malts at different germination periods. ■---■, SSV3; △——△, SSV12; ●---●, FFBL; ○——○, MORI; □---□, KSV4; ●——●, KSV8; ▲——▲, SSV7

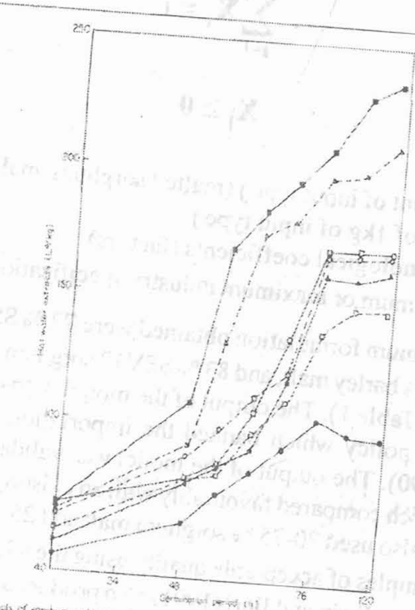

Fig. 7 Hot malt extracts of sorghum malts at various germination periods. ■——■, SSV3; △---△, SSV12; ○——○, FFBL; ○——○, MORI; ▲——▲, SSV7; □---□, KSV4; ●——●, KSV8

Having resolved the problems associated with steeping, malting and have successfully adapted the brewing process of barley malt to suit the sorghum m[illegible], we then turned to the economic aspect. How could we obtain sorghum beer of best value for the least cost? This led us to a cost minimizing linear programming model for the formulation of beer from sorghum malts (SSV3 and SSV12) barley malt, and maize grits. The objective function of the model was to minimise the total cost of inputs (Z) subject to some technological constraints.

That is,

$$\text{Minimize, } Z = \sum_{j=1}^{j=3} c_j X_j \qquad (j=1,2,3)$$

$$\text{Subject to } \sum_{j=1}^{j=3} a_{ij} X_j \le b_i \qquad (i=1,2,3,4----)$$

$$\sum_{j=1}^{j=3} X_j = 1$$

$$X_j \ge 0$$

where

X_j = amount of input type j (malted sorghum, malted barley, maize grits
c_j = cost of 1kg of input type j
a_{ij} = technological coefficients (factors)
b_i = minimum or maximum industry specification of component type

The optimum formulation obtained were 77 % SSV3 sorghum malt, 23 % maize grits and 0 % barley malt; and 83 % SSV12 sorghum malt, 17% maize grits and 0 % barley malt (Table 1). The output of the model with 0% barley malt supported the Government policy which banned the importation of barley malt (Ilori and Olorunniwo, 1990). The output of the model was validated by using it to produce beer samples which compared favourably with an existing commercial beer (Ilori *et al*, 1991b). We also used 70-75 % sorghum malt and 25-30 % unmalted sorghum to produce beer samples of acceptable quality using the adapted mashing profile (Ilori *et al*, 1991c). Ogundiwin and Ilori (1991) also produced stout from roasted sorghum malt and sugar using bitter leaf (*Vernonia amygdlina*) extract as hop substitute for flavouring. The properties of the beer samples and stout (Tables 2-5) met the Nigerian standard and were similar to those commercially available in the market then.

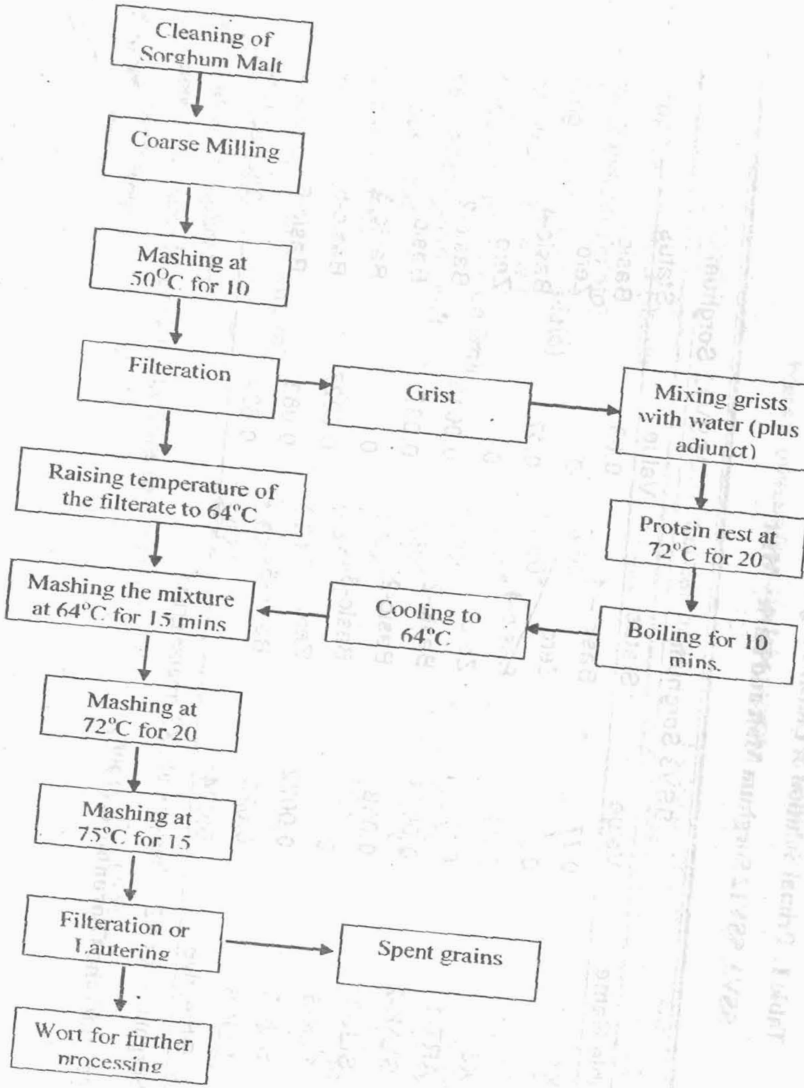

Fig. 8: Adapted Mashing Profile of Barley malt for Sorghum malt.

Source: Ilori, (1990).

Table 1: Primal Solution of Linear Programming Formulation for SSV3, SSV12 Sorghum Malt and Barley Malt

Variable Name	SSV3 Sorghum		SSV12 Sorghum	
	Value	Status	Value	Status
X1	0.77	Basic – 1	0.83	Basic
X2	0	Zero	0	Zero
X3	0.23	Basic-4	0.17	Basic-4
ART-1	0	Zero	0	Zero
SLAK-2	0.0014	Basic-2	0.0018	Basic-2
SLK-3	0.068	Basic-2	0.097	Basic-3
SLK-5	0	Basic-3	0	Basic-3
SLK-5	0.0022	Zero	0.0027	Basic-5
SLK-6	0.023	Basic-5	0.083	Basic-6
Objective	0.624		0.624	

X1 = Sorghum malt X2- = barley malt, X3=maize grists

Source: Ilori and Olorunniwo, (1990)

Table 2: Properties of commercial and malted sorghum beers produced from the laboratory

Property	Commercial beer	SSV3 Sorghum beer	SSV12 Sorghum beer
Apparent extract (°plato)	1.77[a]	1.60[ab]	1.50[b]
Real extract (°plato)	3.63[a]	3.55[ab]	3.40[a]
Original extract (°plato)	11.60[a]	11.85[a]	11.30[b]
Alcohol (% w/w)	3.91[a]	4.18[a]	4.03
Apparent attenuation limit	76.82[a]	86.50[b]	86.13[b]
Real attenuation limit	62.36[a]	70.04[b]	69.91[b]
Colour (°EBC)	11.50[a]	12.00[a]	11.50[a]
Turbidity (°EBC)	0.37[a]	2.51[a]	0.85[a]
pH	4.21[a]	4.25[a]	4.25[a]
Titratable acidity (mg/ml)	1.62[a]	1.63[a]	1.64[a]
Total Sugars (mg/ml)	18.92[a]	18.16[a]	17.30b

a Means of 3 replicates

b Means of the same letter along the same row are not significantly different at 95% confidence interval.

Source: Ilori (1989)

Table 3: Mean scores for taste panel on commercial sorghum beer samples.

Property	Commercial beer	SSV3 Sorghum based beer	SSV12 Sorghum based beer
Taste	3.9[a]	4.3[a]	4.1[a]
Aroma	4.3[a]	4.6[a]	4.4[a]
Appearance	4.4[a]	4.5[a]	4.4[a]
Body	3.8[a]	4.1[a]	4.0[a]
Foam formation and retention	4.5[a]	5.0[a]	5.1[a]
Overall acceptability	4.1[a]	4.2[a]	4.1[a]

a Means of the same letter along the same role are not significantly different at 95% confidence interval.

Source Ilori, (1989)

Table 4: Properties of stout-like drinks from sorghum malts.

Sorghum sample	Input roasted and unroasted	Sugar (%)	Original gravity (°plato)	Apparent extract (°plato)	Alcohol (w/w)	Apparent degree of fermentation (%)	pH	Titratable acidity (g/100ml)	Colour (°EBC)
SSV3	86	14	14.2[a]	2.6	4.5[a]	81.6[a]	4.1[a]	0.17[a]	20.5[a]
	82	18	15.1[a]	2.8	4.9[a]	81.5[a]	4.0[a]	0.17[a]	21.5[a]
LR	86	14	12.7[a]	2.5	3.9[a]	80.3[a]	4.2[a]	0.18[a]	19.5[a]
	82	18	13.6[a]	2.6	4.0[a]	81.0[a]	4.0[a]	0.16[a]	20.5[a]
Commercial Stout	-	-	15.9[a]	3.0	5.2[a]	81.1[a]	4.1[a]	0.16[a]	22.0[a]

a Means with the same letter along the same column are not significantly different ($P < 0.05$)

LR = Local red.

EBC = European Brewing Convection

Source: Ogundiwin and Ilori (1991)

Table 5: Organoleptic properties of sorghum and commercial stout samples.

Sample	Adjunct level (%)	Aroma	Taste	Colour	Foam formation	Mouthfeel or 'body'
SSV3	14	3.4^a	3.2^a	3.1^a	3.0^a	2.5^a
	18	3.5^a	3.4^a	3.3^a	3.1^a	3.2^a
LR	14	3.3^a	3.1^a	3.2^a	3.2^a	2.2^a
	18	3.4^a	3.3^a	3.3^a	3.1^a	2.6^a
Commercial stout		3.2^a	3.1^a	3.2^a	3.1^a	3.2^a

a Means with the same letter along the same column are not significantly different ($P < 0.05$).

LR = Local Red.

Scale for rating aroma, taste, colour, foam formation and mouth feel or body: 5 = Extremely better than R (commercial barley stout) ; 4 = Better than R; 3 = No difference ; 2 = Slightly inferior to R ;1 = Inferior to R (reference sample)

Source: Ilori, (1991)

Based on the yields, market price (cost/kg) of each input and beer (price/litre), the partial productivity of sorghum was computed. The partial productivity (pp) is defined as the ratio of output, to the particular input of interest (Summentti, 1981). Mathematically, partial productivity is given as

$$pp = \frac{C_i Q_i}{r_i x_i}$$

where C_i is the price of output Q_i (beer) and r_i is the cost of sorghum malt (x_i) used to produce the output. Table 6 indicates higher productivity when sorghum malt was purchased at a lower price than barley malt. However, computing the productivity at high costs of sorghum malt produced lower productivity. The policy implication is that sorghum should be available at low cost to be economically better than barley malt as the major input in brewing. Hence, production of sorghum at low cost in sufficient quantity to meet human and industrial uses, establishment of malting plants, adaptation of existing brewing lines to suit sorghum malt, were some of the strategies for achieving this (Ilori, 1991)

A sample modification of the existing brewing line (Fig. 9) which would allow the use of this sorghum brewing technology at a commercial level without the use of external enzyme and at reduced cost was also proposed and its economic viability was established using engineering economy methods (Ilori *et al* 1996).

Table 6: Partial Productivity of Sorghum and Barley Malts in Brewing

Malt type	Cost/kg (Naira)	Partial productivity
SSV3 Sorghum	0.63	17.3
	1.39	7.8
	2.15	6.0
SSV12 Sorghum	0.63	-
	1.39	15.4
	2.15	6.9
Barley	2.15	4.9
	2.24	6.15

Source: Ilori, (1991)

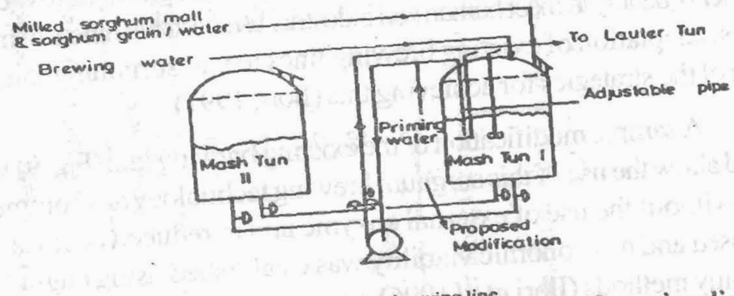

Fig. 9: A simple modification of an existing brewing line

Source: Ilori *et al*., (1996)

At this stage, the development of sorghum beer using local materials has been successfully achieved. What is needed is a scale-up from laboratory to pilot or industrial scale. For this purpose, AIC Limited Ibadan, a company owned by Chief H. Akande, provided fund for our research team, headed by Late Prof J. O. Ogundiwin, to prove our invention at the industrial scale. We produced about 5.5 tonnes of sorghum malt and processed it to obtain over 40,000 bottles sorghum

beer without the addition of external enzymes using the facilities of the International Brewing Plc, Ilesa. The beer produced labelled "Victory Beer" compared favourably with existing brands available commercially. The technology scale-up vindicated the insistence of the Federal Government on local raw material substitution by the industry (Ogundiwin *et al.* 1989).

The question now is "has this technology been adopted by the Nigerian breweries?" The technology is now widely adopted notwithstanding the globalization of trade which allows the inflow of imported products including barley malt into the country. Our recent study revealed high level of compliance by the breweries and other beverage companies to the policy of local raw material substitution. The level of compliance ranged from 40% to 100% and the industry's average is 61.0% (Oyedoyin, 2006).

This level of compliance by the beverage industries had reduced production cost, and did not have adverse effect on the quantity of the industry's products. The implementation of the policy also generated employment as claimed by 70 % of the brewery respondents and saved foreign exchange through reduced cost of importation of barley malt from ₦69m to ₦24m and the elimination of ₦23m worth of malt extract between 1988 and 1999 (Oyedoyin, 2006).

Energy and Environmental Management in the Brewing and other Industries

Our research effort in brewing science, technology and management was not limited to product and process development and economics; it also extended to energy and environmental issues. We discovered that the breweries produced an estimated annual of 1.2million m^3 waste water, 3300 tonnes of spent grains, 20.52 tonnes of spent yeast, and 1650 tonnes of broken bottles among other wastes as by-products. The results also showed that the breweries were improperly discharging some of these wastes into their surroundings (Akinwumi *et al*, 2000). Most existing strategies adopted by the breweries for environmental management were primarily out of process, and thus reactive end -of -pipe- strategies. In the breweries, the dominant waste water treatment technology was aerobic oxidation ponds, which is the most rudimentary in their class of environmental technology. Other strategies include dumping of waste and other proactive cleaner production such as the re-cycling and sales of bye-products (Ilori *et al*, 1999). Notwithstanding, most of the residents (70%) of these breweries surroundings interviewed, reported the discharge of waste-water. and pollution of their environment by the breweries. The most commonly reported pollution factors were odour, fouling of streams and land. The pollution also had impact on the ecology, land, agriculture, structures, health and socio-economic lives of people of the brewery surroundings. These are indications of poor waste management in the industry. The reaction of residents around the breweries to the problem was weak, as only 21% of respondents made attempts to combat it (Akinwunmi *et al*, 2000).

Our study of energy consumption pattern in a Nigerian beverage industry revealed an increase in the growth of energy intensity, coupled with a simultaneous decline in productivity. Furthermore, combustion analysis of the boilers revealed the possibility of making fuel saving of about 12 % by improving boiler efficiency alone (Akinbami *et al*, 2002). We also found that the actual energy demand per year (4.28-8.58 BOE per 100 BOE) for processing crude oil into final products in Nigeria exceeded the stipulated refinery standard of 4 barrel of oil equivalent (BEO) per 100 BOE. This energy inefficient demand pattern was due to lack of optimal energy mix, and non-compliance with tim-around-maintenance schedule (Jesuleye *et al*, 2006). Strategies such as utilizing energy efficiency improvement programmes and optimal energy mix both at firm and national levels were recommended.

Non-Alcoholic Beverage Production.

The inward look has also revealed a lot of resources which could be used for the production of ethanol and non-alcoholic beverages. For instance plantain, breadfruit, sweet cassava and potato are readily available in the country.

We have therefore geared our research efforts, sponsored by the International Foundation for Science (IFS) Sweden, towards the development of non-alcoholic beverages from sorghum malt and breadfruit, plantain, potato or sweet cassava using the endogenous enzymes of the malt and a little quantity of external enzymes for saccharification. The original gravity of the breadfruit, cassava and plantain-based samples were higher than those of other samples (Table 7).

Table 7: Properties of Malt Drink Produced from Sorghum and Various Adjuncts.

Malt Drink	Volume (litres/kg)	pH	Extract (°Plato)	Colour (°EBC)	Viscosity 10^{-3} PAS	Total sugar (mg/100l)
Potato-based	4.70 ^{a}	5.23 ^{a}	15.10 ^{a}	387.00 ^{a}	1.132 ^{a}	164.6 ^{a}
Cassava-based	4.65 ^{a}	5.44 ^{a}	15.50 ^{a}	350.00 ^{a}	1.11 ^{a}	160.5 ^{a}
Breadfruit-based	4.58 ^{a}	5.12 ^{a}	16.00 ^{a}	387.50 ^{a}	1.527a	170.0 ^{a}
Plantain-based	4.50 ^{a}	5.33 ^{a}	15.60 ^{a}	350.00 ^{a}	1.401 ^{a}	161.0 ^{a}
Commercial**	5.10	5.10 ^{a}	15.00 ^{a}	320.00 ^{a}	1.134 ^{a}	158.5 ^{a}

a Means with the same letters along the same column are not significantly different ($p < 0.05$)

** Commercial brand produced from sorghum only.

Source: Ilori *et a.,l* (1977a)

Similarly, sensory evaluation indicated no significant difference (p d" 0.05) between the potato and plantain-based samples in terms of flavour. However, the raw flavours of the breadfruit and cassava were slightly noticeable in their products. The foam formation and stability in the plantain-based beverage sample were better than those of the reference sample, while those of other samples were very poor. However, incorporating 5-10% plantain improved these qualities in the other samples. All the samples were adjudged to be acceptable in terms of the overall quality (Ilori *et al.,* 1997a). A micro brewery has been proposed for the commercial exploitation of these research results (Fig. 10). The engineering economy studies of the micro-brewery showed positive net present value (NPV) at 75% and 100% capacity utilization (Table 8). This indicates that the result of this research may lead to a successful innovation if appropriate funding, management and business strategy are employed for its exploitation (Ilori *et al.,* 1997b).

Table 8: Cash flow (US $) for the microbrewery

Parameter	Capacity A	Capacity B	Capacity C
Investment			
Capacity Investment	139.160.00	139.160.00	139.160.00
Reproduction Expenses	14.034.44	14.034.04	14.034.44
Sub-total	***153,194.44***	***153,194.04***	***153,194.44***
Annual Disbursement			
Raw Materials*	6.979.48	10.469.21	13.958.95
Equipment Running cost	9.494.60	12.381.66	15.477.57
Maintenance	8.610.80	11.481.07	14.351.34
Labour	6.964.30	8.571.44	10.714.30
Sales promotion	3.658.54	5.487.80	7.317.07
Sub-total	***35,707.72***	***48,391.18***	***61,819.23***
Revenue			
Sales of Malt drink	58.536.59	87.804.88	117.073.17
Salvage value	18.272.68	12.951.12	10.975.61
NPV	***76,809.27***	***100,756.00***	***128,048.78***

*Varied depending on the malt type.

Source: Ilori *et al.,* (1997b)

Ethanol Production

Our research work on hydrolysis of breadfruit and cassava starch by enxymes of sorghum and acid yielded appreciable amount of sugar which was then fermented to produce ethanol (Solomon *et al.*, 1994). The engineering economy studies of the ethanol production via plant enzymes and acid hydrolysis at small scale level appeared to be economically viable, with positive net present values (NPV). Hence, breadfruit and cassava which are available in abundance as earlier mentioned could be used for commercial production of ethanol (Ilori *et al.*, 1996). In Brazil and other countries, potato is used industrially for the production of starch, glucose, syrup and ethanol. These research efforts conducted in 1996 support the current Government initiative on the utilization of cassava for ethanol production.

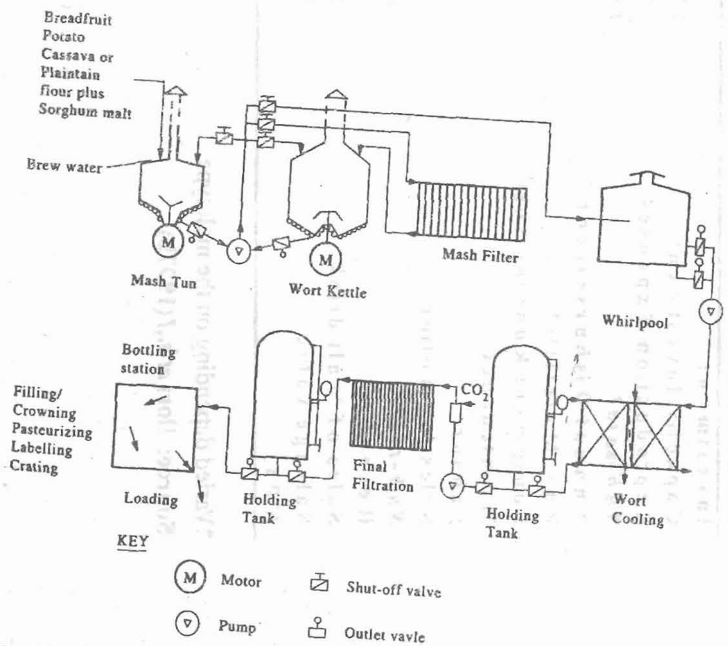

Fig. 10: Process flow diagram for beverage production from some tropical crops at small enterprise level

Source: Ilori et al (1997b)

Weaning Food Research and Development.

Locally produced weaning foods should be preferred to imported ones for obvious reasons. Oilseeds were considered as an alternative and innovative source of proteins since they contain proteins of high biological value (Ilori and Ige, 1991). Hence, we used a cost minimization Linear Programming (LP) decision model to simulate a commercial milk based diet using plant protein source. The LP model gave an optimum mixture of 48.5 % pre-gelatinized maize flour and 3.9 % defatted soyabeans flour that formed an ideal diet which had no significance difference ($p < 0.05$) between the control diet in terms of the properties studied. The performance of the formulated diet was satisfactory and promising as a potential mixture in the formulation of weaning food in the developing countries (Fashakin *et al.*, 1991).

Prof. Fashakin's research effort on weaning food was scaled up to pilot plant level, courtesy of the Federal Ministry of Science and Technology. However, this technology and many others used for processing oilseed meals developed in the laboratories have not been commercialized. Modern methods have nevertheless been introduced to upgrade the traditional technologies for processing oilseed meals and other traditional foods (Taiwo *et al*, 1997). Policy measures such as development of capabilities to create, select and initiate production for commercialization of the laboratory food products and further integration of modern technologies for processing these foods were prescribed (Ilori, 1993). The Local Governments (LGs) also have a role to play in this regard. For instance, each LG should identify indigenous technologies peculiar to its locality with the purpose of upgrading or improving such technologies and creating jobs for the people (Ilori, 1990).

Synthetic whole Wheat Bread

Adewusi and Ilori (1994) found that red and white sorghum spent grains which are by-products of beer production contained 23.4 and 19.3 % crude protein, 54 and 43 % dietary fibre, 1.44 and 0.78 % ash, 4.5 and 3.2 % hexane extract and tannin content of 7.5 and 1.0mg/g catechin equivalent respectively as well as adequate essential amino acids except lysine which was limiting. The spent grams which contained a high level of protein was usually fed to animals. So the simple question is why should a dog snore when man has no place to sleep. We therefore incorporate the spent grains at 15 % into wheat flour for bread production. The product which was accepted looked exactly like wheat bread; hence the term synthetic whole wheat bread. Thus, in developing countries where protein malnutrition seems endemic, spent grains obtained cheaply from breweries could become a good source of additional protein if incorporated into baked products and food blends.

Preservation of Nigerian Soft Cheese (Warankasi)

Wara, a highly nutritive Nigerian soft cheese, is usually produced at cottage level. However one of its main problems is its short shelf life which renders it unacceptable for human consumption after twelve hours at ambient temperatures. Preservation by refrigeration prolonged the shelf life for only a few days and freezing often leads to graininess and product disintegration. The domestic deep-fat frying produced fried *wara* of poor nutritive quality (Ogundiwin, 1983). However when we preserved *wara* in brine whey by a canning process described as a hot-filled sterilization (HSF) method, it produced canned *wara* with no significant difference ($p<0.05$) in the characteristic flavour, texture, and appearance after a period of six weeks when compared with the fresh *wara* (Ilori, 1983, Ogundiwin and Ilori, 1986).

Sea food

Periwinkle, which is available in large quantity along the West African coast, contains most of the essential amino acids in adequate amount for human nutrition and was found to be a good source of high quality proteins for human beings. Strict environmental control of the harvest areas, adequate method of processing these animals and other strategic measures were recommended to ensure safety under production and distribution and consumption of the product (Ariahu and Ilori, 1992).

The Food Service Industry

Ilori and Awoyinka, 1994 investigated the hospital foodservice as an example of an institutional foodservice industry. We found inappropriate methods in this sector and recommended management practices for improving food preparation and service in hospitals.

Biotechnology R&D and Innovation Management.

Biotechnology is a body of techniques that uses living organisms, or substances from those organisms, to make or modify a product. It also includes techniques used for the improvement of the characteristics of economically important plants and animal and for the development of micro-organisms to act on the environment. From this definition, biotechnology is as old as human society, as is evident from activities such as fermentation of wine and other food products. Over the centuries, the practices gradually developed in empirical fashion to a high degree of perfection (UNIDO, 1989). The latest technological developments in biotechnology have led to more improvements of a completely different order of magnitude in agriculture (Sasson, 1994), and relieved farmers from many of the traditional constraints and hazards. We investigated the applications of biotechnology, especially new biotechnologies in relation to mushroom cultivation and biogas production in Nigeria.

(i) Economics of Mushroom Cultivation

Mushrooms had been utilized as food for more than two thousand years. The mushrooms gathered from farmland, fields and meadows were valued and priced as delicacies. The food value of mushrooms is very high. Apart from containing high quality protein, minerals, and vitamins, they contain low cholesterol and sodium, thus making them ideal for patients with certain heart or kidney diseases (Fasidi and Kadri 1990, Zandrazil and Dube, 1992). The cultivation of these fungi started in China in 600 B.C. and spread to Europe and America in the 18th centuries, respectively. The industry has since developed in many Asian countries and plays a significant role in their economies (Quimio, *et al* 1990).

Mushroom cultivation for household consumption using palm waste and scelereotia is part of the indigenous knowledge system in Nigeria. Efforts have been made to study the biotechnology and cultivation of some local varieties. Since mushrooms have been shown to be rich in some vital nutrients, Ilori *et al.*, (1997) proposed an approach to utilize this technology to create jobs and supplement the dietary nutrient intake of the people. However, their commercial production using modern knowledge system (biotechnology) is very limited in Nigeria. Based on previous studies on mushrooms, cottage level technology was proposed for the commercial exploitation of mushroom biotechnology in Nigeria. The profitability of the mushroom cultivation technology was established at 2.5, 3.75 and 5.0 tonnes capacities per annum using various investment options. Option A entails the complete processes of spawn production and mushroom cultivation. Option B involves purchasing the spawn from a separate organization and then using the spawn for mushroom cultivation, while option C which was considered for only *P. oestreatus* involved purchasing ready-to-fruit spawned bags for incubation and fruitification. The engineering economy revealed that the venture could be profitable with selling price above one hundred and seventy four naira (₦174) and one hundred and fifteen naira (₦115) per kilogram of *Volvariella volvacea* and *Pleurotus ostreatus* respectively. Profitability and sensitivity analyses showed option C to be a relatively risky investment which could easily be affected by competition and price instability. Option B is the most favoured for investors because of the lower capital investment requirement and favourable profitability indices. The business risk is also shared between the mushroom growers and spawn producers (Ilori et al, 1999).

From our market research, we found the existence of sufficient market for fresh rather than canned or dried mushroom in Nigeria. We also established that demand was negatively correlated with income of the potential customers ($r = -0.18$, $p < 0.05$) implying that investor would optimize their market opportunities by employing low price market strategies (Adeniyi *et al,* 1998).

(ii) Engineering Economy Studies on Biogas Production

Biogas derived from animal wastes and other biomass offers a convenient and replenishable source of energy needed by householders. However, developing and utilizing this desirable, modern, ecology-oriented form of appropriate technology remains unpopular in Nigeria, partly because of lack of information on its economic viability. Therefore to stimulate householder's interest in the development and utilization of bio-gas technology in order to solve the perennial cooking energy problems at household level in Nigeria, we carried out the engineering design requirements, and used the discounted cash flow methods to evaluate a 6.0 m^3 family sized biogas project using cow dung as substrate in Nigeria. The financial analysis showed positive net present value (NPV); internal rate of return (IRR), and benefit /cost (B/C) ratio and payback period of 0.05 million naira, 17.52%, 2.26 and 6.6 years respectively. This implies that the project has a good economic potential in Nigeria (Adeoti *et al*, 2000). We have proposed three scenarios for incorporating biogas into household energy mix in Nigeria. If any of the scenarios is adopted, at least between 357 – 60,952 tons of CO_2 and other gaseous emissions into the atmosphere would be avoided annually (Akinbami *et al*, 2000).

(iii) Agricultural Biotechnology R&D Management

Nigerian Government has made tremendous efforts in the formation of National Science and Technology Policy which implicitly emphasises biotechnology development for economic development. However, it has not been commensurably translated to generate new technologies for industrial use. For instance, tissue culture and other biotechnological techniques have been applied for the production and processing of cocoa and palm produce. However, we found that the benefit derivable from this application was still very low when compared with what obtains in the international scene (Ilori *et al*, 1994).

Instruments and strategies for implementing this and other related policies to bring about full participation by the private, public and academic sectors include institutional and financial instruments. Others are creating complimentary capabilities such as provision of institutional facilities, foreign exchange to import biotechnology inputs which are not available in the country and development of bio-processing technologies for scale-ups (Ilori *et al*, 1994). Furthermore, critical management issues for the promotion of biotechnology R & D and innovations for economic development in Nigeria were reported by Irefin *et al*, (2005) to include development of core competence, bio- safety regulations, infrastructural facilities and strategies for linking research to end users. The traditional base of biotechnology research and development had been the academic institutions. We therefore suggested adjustments in the tertiary institutions and research institutes

in order to stimulate biotechnology R & D and innovation. These adjustments are in the areas of promotion of entrepreneurial culture within the academic environment, staff motivation and development of the intermediate, peripheral and bridging institutions (Irefin *et al*, 2005).

Research on New Product and Process Development in the Industry

Developing new products is a risky business endeavour, because a technically feasible innovation might not be economically profitable, and the product may not survive the commercialization process. Cooper (1978) and Crawford (1979) reported that success rates for new inventions ranged from 1 % to 85 %. The results of a study we reported in 1999 showed that the food companies in Nigeria invested between zero and 2.5 % of their annual turnover in Research and Development (R&D), with four of them investing less than 0.5 %. Four of the companies used the integration and overlapping approach of all the seven stages of new product development process. Nine of the companies developed new products through a multidisciplinary team of professionals. Most of the innovations were incremental in nature (Ilori *et al*, 2000).

In Nigeria, we also found that 64.67 % of new food products developed by firms were clear success, 12.5 % slight failure and none was a total failure, an indication of a high potential growth for the industry. Our results further showed that defense of market share position, maintenance of position as innovator, establishing a foothold in a new market were the most important factors motivating new food product decisions. This is an indication that new product decisions were market-driven rather than technology pushed. Product uniqueness also ranked as the most important contributor to new product success. This implies that the food companies should continue to monitor trends in the market for the purpose of developing new products to satisfy identified markets (Oke et al, 1999), and building competitive advantage.

In the area of process innovation, we found that Information Technology (IT) improved both the efficiency and effectiveness of the decision making process in product marketing in a multinational food company. It had impact on some marketing variables such as product popularity, promotion/advertisement, distribution and sales (Adetayo *et al.*, 1999). Information Technology also enhanced operational efficiency in the banking industry in Nigeria (Ugwu *et al.*, 2000).

COMMERCIALIZATION OF R&D RESULTS IN NIGERIA

Our educational and research institutions have produced a lot of research results and inventions which are readily available in these organisations. These R & D results cut across various disciplines and industrial sectors. A few of them have been commercialized, and a lot are still in the shelves awaiting commercialization. This is unlike what obtains in the developed countries where development of new and improved products and processes depend heavily on academic research findings. We therefore became interested in researching into issues that influence commercialization of R & D results and inventions from the academia.

(i) Industry-academic Linkage

The local industrial sector is often small and made up of production units majority of which cannot undertake R&D. This sector is supposed to interact with R&D organizations in order to meet their R&D needs. However, in most developing countries including Nigeria, such interaction or linkage is very weak. In our studies, we found that the major ties between the Obafemi Awolowo University and industries in its neighbourhood were found to be in consultancy activities such as training workshops, short courses and student industrial training. Little or no research ties or joint ventures were observed. This is probably due to reasons such as communication gap, cultural differences in terms of researchers' concentrating on publications for promotion only, and lack of research facilities and infrastructure that could meet the need of the industries (Oyebisi *et al.*, 1996).

The work culture of research and educational institutions, indicates that they are contented with Government patronage. They enjoy autonomy and are not accountable to the industrial users of their R&D results. Consequently, these institutions, especially in Nigeria over the years preferred to define their R&D agenda without any interaction with potential users. This has been described as a major weakness in the management of R&D and innovation (Oyewale, 2003, Irefin *et al.*, 2005). The domestic industries' lack of interest in the local research outputs has been associated with the strong preference for foreign technologies. This is one of the reasons why domestic industries are not keen to establish in-house R&D or patronize local academia for their research needs. This situation also informed why some local industries lack technological innovation culture and do not show interest in engaging quality scientific and engineering personnel in industrial R&D. The lack of confidence in the quality and competence of local S&T professionals, especially expressed by foreign-based multinational companies affected the linkage between academia and industries (Oyebisi *et al*, 1996). On the part of indigenously owned industries, the level of appreciation and response to the issue of collaboration with academia was associated with the level of education of the local entrepreneurs as educated or professional elite entrepreneurs are more receptive than the lower class entrepreneurs (Nnadi, 2002).

Lack of effective networking among the research organizations also leads to duplication of research efforts and waste of resources (Oduola *et al.*, 2005). Linking R&D to industry is therefore a desirable strategy for technology

development and achievement of industrial growth. It also facilitates the identification, characterization and development of local material bases, new products and new processes for industrial activities.

The models for the transfer of technology from the academia to the industry include information, licensing, venture capital, large company joint venture, the incubator-science park and ferret models. Application of these models was lacking between Obafemi Awolowo University and industries in its neighbourhood. Strategies for using these models as facilitator for technological collaborations between the academia and industry were recommended. The collaboration must be controlled to avoid excessive business orientation of the University that may lead to reduction in fundamental research and loss of knowledge due to trade secrecy (Ilori *et al.*, 1995, Oyebisi *et al.*, 2001).

However, to further enhance the success of commercialization, some interface organizations are usually established by the Governments and research organizations. Such institutions facilitate communications between academic and industrial environment, and coordinate research-industry linkage activities, without unduly disrupting activities within the organizations. These institutional establishments include:

a) Industrial Liaison/Technology Transfer Office

Industrial Liaison/Technology Transfer Offices are established by educational institutions and research institutes to liaise between them and industry. These Offices, created to reduce the rigour of decision making process, are usually involved in the processing, licensing and general management of patents and other intellectual property that are developed in their parent organizations (Ilori and Irefin 1997). From a recent Ph.D work which I co-supervised, out of 10 universities and research institutes in Nigeria studied, only one claimed to have established an Industrial Liaison Office (Oyewale, 2003).

b) National R&D Brokerage Organizations

These are organizations that are involved in matters relating to patents and their exploitation. Activities of the organizations cover the whole country and they have large materials and human resources with which they support innovations. The National Office For Technology Acquisition and Promotion (NOTAP) is the organization that plays these roles within the Nigerian National Innovation System. The Office was established by the Federal Government by Decree No. 70 of 1979. This organization is also involved in the promotion and commercialization of indigenous inventions, and the provision of information from the Patent Information and Documentation Center (NOTAP, 1999).

c) Technology Business Incubation Center (TBIC) / Science and Technology Park

A Technology Incubation Centre or Science and Technology Park is a property-based organization that supplies shared facilities for nurturing young firms (tenants) for short periods. Incubators usually provide their tenants with production space and offer them business, administrative, and technical support services, all at subsidized rates. While staying at the incubator, the company produces at a low scale, stabilizes its production system, establishes its presence in the industry and masters the business environment in which it is operating. On graduating from the incubator, the incubated company relocates to an industrial estate to operate.

Sponsors of incubators include Government (national, state, local), educational institutions, research institutes, development agencies, and the private sector each with its own motives for establishing the incubators. As at year 2000, one Technology Business Incubation Centre (TBIC) had been established in each of 14 States in Nigeria by the Federal Government (Ukegbu, 2000).

In our recent studies, we found that between 1993 and 2003, companies in the Agege TBIC experienced average capital growth between 40 – 820%, and increased turnover. Furthermore, diffused locally developed technologies contributed 70 -80 % of the technologies used at the center (Adeniyi *et. al.*, 2005). These results confirmed the existence of potential for economic and technological development through the TBIC.

Science and technology parks are usually associated strongly with a University or research institute to encourage the formation and growth of spin-off firms and also stimulates innovative activities in existing enterprises. They have been used by some countries for their industrial development. For example, between 1960 and 1990. Taiwanese Government developed 71 industrial parks while private investors developed 11 and these parks had been major stimuli for industrial development of the country (Xue, 1997).

The National S&T Parks that is located in Sheda Village in Abuja would be the first of its kind in Nigeria, when it becomes fully operational. The Obafemi Awolowo University, Ile-Ife, has also started preliminary work on the establishment of her S&T Park. Mr. Vice-Chancellor has been magnanimous enough to appoint me to serve as the Chairman of the committee to actualize the programme. More of these parks need to be established in Nigeria, as their availability would generate many spin-off firms.

(ii) Funding the Commercialization of R&D results and innovations

Banks do not finance R&D and innovation stages, but wait till the phase of production before they provide financial supports. Therefore commercialization of R&D requires a special type of fund called Venture Capital. Venture capital investments are usually in the form of equity, quasi-equity and /or conditional loan which are offered to new, high-risk, high-tech spin-off firms. Guild and Bachher, (1996) identified three classes of Venture Capitalists. These are Private Venture Capitalists (PVCs), Public Venture Capital Funds (PVCFs) and Business Angels (BAs). The PVCs are professional or institutional investors who operate on behalf of private shareholders. The PVCFs are owned by State, Federal, or Regional Governments while BAs are individual investors. Venture Capital Organisations (VCOs) usually groom spin-off firms into large companies. As the business becomes well established, their shares are offered for sale at the Stock Exchange to several shareholders. This ensures the survival and sustainability of the company.

To date, the only VCO operating in Nigeria is the National Risk Fund. Therefore, it is important for Governments at all levels to promote the creation of venture capital organizations and encourage the emergence of business angels to finance technological innovations in Nigeria. A possible source of VC funds in Nigeria is the Small and Medium Industries Equity Investment Scheme (SMIEIS), which was initiated by Nigerian Bankers Committee. As at the end of 2004, the sum of ₦22 billion had been accumulated for the scheme, which was launched on August 21, 2001 (Sanusi, 2003). Out of this sum ₦7.7 billion representing 35 % had been accessed for financing 147 projects since inception. Indigenous cottage level industries such as metal casting for the production of household utenziles and garment making should also have access to this fund. This will ameliorate the economic, environmental and production problems usually encounter by the operators of these businesses (Akinwunmi *et al., 1996,* Ibitoye and Ilori, 1998). A reasonable percentage of this unutilised accumulated fund could also be dedicated to VC formation (Oyewale, 2003).

(iii) Research Policy and Strategic Management

Many policies covering different sectors of the Nigerian economy have been put in place to guide the process of development. Science and Technology policy is aimed at directing and coordinating R&D towards meeting the needs of the society, especially in the field of agriculture, industry, health, among others. Without solid S & T policy, the industrial and other related policies will only promote commerce. The industrial policy promotes and increases productivity predicated on intensive research into local raw materials as input to manufacturing, and the acquisition of engineering design, fabrication skills, as well as adaptation of modern technologies and machinery (Emovon, 1999). The National Economic

Empowerment and Development Strategy (NEEDS) like all other related policies also emphasize the development of an industrial sector (including micro, small, medium enterprises) that will be internationally competitive. This is with a view to enhancing sustainable economic development, employment generation, wealth creation and poverty alleviation. The success of these policies is anchored on the nation's commitment to Science and Technology (Faborode, 2005). When the outputs of these policies are compared with those of the advanced countries, the S & T work in Nigeria has a status that is peripheral when measured against industrial production in the west. Consequently, we have not been able to come up with an adequate industrial production that can effectively compete in the global market. This implies that most of these policies are defective in either formation or implementation (Sanni *et al*, 2001). The exportation of raw cocoa beans was banned in 1990, with a view to adding more values to the product locally before exportation. The ban was later jettisoned, despite the handsome benefits that could be derived in terms of value addition, job and wealth creation. This was because the existing processing plants could not cope with the amount of cocoa beans produced in the country. Policy guidelines to expand processing facilities and internal consumption of cocoa through the development of new cocoa-based products were recommended (Adeniyi *et al*, 1996).

Research policy and strategic plans which should flow from National S&T and other policies, is lacking in most research and educational institutions in Nigeria. As a result, research planning is not systematically carried out; research priorities and targets are not usually well defined. Furthermore, little or no attention has been paid to the economic viability of the projects, while the focus is mainly on the technical aspects of research projects.

(iv) Information on Commercialisable Inventions and R&D Results

One of the main reasons for low utilization of R & D outputs from educational and research institutions by industrial firms was that industries were not aware of them. This deficiency may be due to information gap, whereby little or no publicity is made on the research outputs and their possible usefulness in the production of goods and in provision of services (Ilori and Ige, 1991; Ilori, 1992).

Various efforts have been made in the past to address this information gap. For instance, the National Center for Technology Management (NACETEM) at Obafemi Awolowo University, Ile-Ife was Commissioned in 1994 to develop a database of inventions and research results from research organizations including tertiary institutions in Nigeria. The National Office for Technology Acquisition and Promotion (NOTAP) was also mandated to collate research findings, patent them, provide funds and relevant complementary information for their commercialization (NOTAP,

1999). The Federal Ministry of Science and Technology (FMST) published the profiles of some of these inventions/research results with a view to making them available for prospective entrepreneurs for commercial production. Earlier in 1992, the Raw Materials Research and Development Council published investment profiles for processing of local and secondary raw materials into industrial outputs. These publications should be reviewed periodically to make them relevant to the end-users. It is believed that small and medium investors would find them useful (RMRDC, 1992).

(v) Technological Entrepreneurial Culture in Educational and Research Institutions.

Technological entrepreneurial culture is the training of the mind for the urge to commercialise technological R&D results and innovations. The culture encourages students and researchers to exploit their research results. This culture is not adequately developed in Nigeria, and it is usually considered as gambling by many people. Many tertiary educational institutions in Nigeria including OAU are trying to introduce entrepreneurship studies into their curricula to promote commercialization of R&D results and self-employment.

(vi) Provision and Maintenance of Infrastructure and Laboratory Facilities

Infrastructure is the shared basic physical facilities necessary for a community or society to function. It includes the operation and maintenance of facilities, structures, and associated equipment and services that facilitate the production and flow of goods and services between individuals, firms, and governments. Infrastructure includes power, telecommunications, water supply, sanitation sewerage, waste disposal, and transportation services among others. These facilities also have significant influence on the outputs and general performance of research organizations.

Our research effort showed that the Nigerian Innovation System was characterized by the existence of inadequate S&T infrastructure, particularly in universities, polytechnics and public research institutes (Oke, 2005). It has always been difficult to procure and keep scientific equipment in proper working condition. Most equipment is imported, because there is no internal capability to design and fabricate modern sophisticated scientific machinery. The ability to even maintain the imported items are very limited (Ogbimi, 1990). As a result, most laboratories are ill-equipped for carrying out research at the frontiers of S & T (Oyebisi *et al* 1999), A consequence of this research environment is that many creative researchers have left the country for other places where these facilities are available, and those trained abroad have refused to come back home. Those of us who preferred to stay at home are under utilized (Ilori *et al*, 2001) due to a dearth of facilities.

Infrastructural facilities are also immediate inputs into production, and their costs have direct effect on costs of firms' products, competitiveness and profitability. For instance, in our study, the low productivity experienced by the small-scale food manufacturing companies in Nigeria, had been strongly linked to some factors, which include irregular power supply and lack of standards for locally fabricated equipment and spare parts (Taiwo *et al*, 2002). Our work on maintenance management also showed that poor record keeping, low compliance with maintenance schedule, and deficiencies in indigenous technological capability (ITC) for manufacturing spare parts and machines limit maintenance effectiveness in the manufacturing industries (Adeniyi *et al*, 2004).

(vii) Motivation of Innovative Researchers/Industry

Researchers and students that generate inventions usually fail to venture into commercialization of their results because of the fear of uncertainty in the business world. However, the tacit nature of the inventions may require the inventors to work closely with the industrial firms that intend to exploit the inventions. These activities would take researchers out of the institution/institutes for a while, they are therefore cautious about embarking on such activities. However, researchers could be motivated if their employment conditions are modified to allow them to nurture such projects outside their institutions/institutes for a period, and later return to their jobs.

Formulation and implementation of similar policies on nurturing spin-off companies by researchers outside their institutions/institutes, may encourage Nigerian scientists to venture into commercialising their inventions, and at the same time, reduce the risks faced by the prospective academic entrepreneurs.

Lack of incentive packages to attract the industrial sector to get involved in risky ventures such as commercialising indigenous inventions and R&D results, is a significant constraint to the development of local innovation capability. Such motivation could be in form of benefits such as pioneer status, which would provide extra advantages to the firms in form of tax holiday, export promotion, and tax exemption on capital equipment. Other incentives could be in form of provision of matching grants for R&D costs incurred by industrial firms to encourage them in investing on R&D either within their organisations or R&D institutes/institutions within Nigeria.

(viii) Patent Education and Effective Enforcement of Intellectual Property Rights

Protection of intellectual property rights of patent holders is a critical aspect of technological innovation, as it encourages people to be innovative. In the Ph. D work which I mentioned earlier, we found that the level of patent education

among Nigerian researchers was low, as most of them were not aware of what patent entails. Although 90% of researchers in Nigeria claimed to have commercialisable inventions, very few of them had protected their inventions with patent, while only 20% of the institutional respondents have patented some of theirs (Oyewale, 2003). We also found that majority of the researchers in Agricultural Biotechnology did not patent their research results because of lack of interest (45%), ignorance (32%) and rigours of the procedure (32.3%) (Irefin *et al.*, 2005).

The ownership structure of the patents generated in the institutions/institutes must be designed to ensure that the researchers and other staff involved in their generation are adequately compensated and motivated. Such motivation was provided by the change in US patent law in 1980, and resulted into seven-fold increase in university patents over a period of 20 years (OECD 1998). Giving the researchers part, a percentage of the patents that emanate from Government-funded researches may also serve as incentive to Nigerian researchers.

CONCLUSION AND POLICY IMPLICATIONS

From the discussion so far, one can conclude that the Nigerian Innovation System is inherently weak in achieving the desired target of a knowledge-based and sustainable industrial economy. There is a growing pressure in terms of improving funding and developing appropriate mission, for research institutes and educational institutions to remain relevant in human resource development and knowledge generation for National industrial development. This would require a total transformation in ownership, strategy, management processes, resources, organization and culture of the institutions. The implementation of the restructuring program is an imperative for the efficient management of these institutions for increased productivity and measurable impacts. Three core areas that should be considered in this restructuring process include:

i. upgrading laboratory facilities, practice and methodology;
ii. launching a promotion and marketing programme for research and technological organisation's corporate image, marketing their existing services, identifying and evaluating new opportunities, and
iii. enhancing staff capability in priority areas through an intensive programme of technical training and industrial exposure (Nsa, 2003).

Concerted efforts need to be made to quantify and evaluate the economic viability of R & D outputs in the country, for them to be relevant and meet societal needs (Oduola *et al* 2006). Capability for translating the research results into commercialisable products should be nurtured through effective linkage between the academia and domestic industry.

A model hybrid coalition capable of resolving cultural differences between the academia and the industry has been proposed. The model will create a forum where effective means of communication would be developed and the two sectors would have the opportunity of interaction and exchange of ideas in an atmosphere of mutual trust and respect (Oyebisi and Ilori, 1996). Under this environment, both parties, together with Government, could establish the technological needs of the industry that requires R&D intervention and get involved in joint venture projects. Joint implementation of projects from research, technology development to production and marketing is feasible under this arrangement. This will ensure that only technology or R&D projects that are relevant to and of direct application to the industry are embarked upon (Ilori *et al.*, 1995).

For S&T to succeed in promoting development, formulation and implementation of R&D policy and strategic planning should occupy a central position in the research institutes, universities and other tertiary institutions. The strategic planning should flow out from the National S&T, Industrial and other relevant policies. The universities, polytechnics and research institutes should build intellectual capital around their core competencies and seek for opportunities to spin-out new technology-based enterprises arising from their R & D outputs and inventions. They should ensure that all S & T activities are aligned with their strategic direction. The growing changes of global scientific and business environment demand global partnership for future survival of our educational and research organisations. They should therefore reach out to other global institutions and seek opportunity for international projects and partnerships.

Business units or Science and Technology parks having strong affiliation to educational and research organisations should be established to promote R&D markets and client industry relationship. Appropriate policy measures need to be put in place to encourage greater investment in local R&D by industry. The contributions of the private sector in support of R&D should be enhanced to be greater than that of Government. Government should put in place policy instruments such as tax incentives for R&D in order to encourage and promote private sector expenditure on R&D. A more robust patenting regime should also be put in place. Provision of adequate infrastructure and standardization of locally fabricated equipment are necessary for effective operation of the Nigerian Innovation System.

Concluding Remarks

Mr Vice Chancellor, Sir, I want to end this lecture with a brief summary of my professional accomplishment in teaching, research and services. Many postgraduate students have passed through my supervision. These include 7 Ph.D, and more than 20 M.Sc candidates. I am currently supervising 4 Ph.D candidates at O.A.U., and one at the Department of Management Science at Ladoke Akintola University of Technology Ogbomoso and several M.Sc students at O.A.U.

In collaboration with colleagues, my research efforts have produced about 80 publications out of which some were reviewed for this lecture. Just of recent, I was given a research award in recognition of my contribution in the field of Technology Innovation Management by the International Association for Management of Technology (IAMOT), U.S.A. I was also selected '' ***Man of the Year 2002"*** by the American Biographical Institute Board of International Research.

Some of the service positions which I have occupied include Acting Director and Director of Technology Planning and Development Unit for 4 and 3 years respectively, Vice Dean of the Faculty of Technology and member of various Committees at the Units, Faculty and University levels, I have also taken part on two occasions in the review of the National Science and Technology Policy, and in the design of National Policy on Materials. I also served at the Presidency as a S & T professional, assisting the Presidential Adviser on S & T and Human Resource Development in Abuja.

All the achievements were made possible through God Almighty and the supports of my wife, children, professional colleagues, friends and students. I am grateful to them, and to the University for providing the enabling environment for these achievements.

Thank you for your attention and patience.

References:

Adeniyi, A.A., **Ilori, M. O.**, J.B. Akarakiri and B.O. Solomon (1999): Technological and Economic Evaluation of Mushroom Cultivation in Nigeria. *Ife Journal of Agriculture.* 20, 10-27.

Adeniyi, A.A., **Ilori, M. O.** and Sanni S.A. (2005). Evaluating Strategies of Maintenance Management in Selected Manufacturing Industries. *Nigerian Journal of Engineering Management,* 5, 4, 1 – 14.

Adeniyi, A.A., Shittu, A., Akarakiri, J.B, and **Ilori, M. O. (2005):** "Evaluating Technology Business Incubation Programme as a strategy for developing Small and Medium Enterprises in Nigeria". *Nigerian Journal of Industrial Systems Studies.* 4 (1): 1-13, 2005

Adeniyi, O.R. and **Ilori, M. O.,** (1996): Assessment of Some Cocoa processing Firms and Government Policy on the Exportation of Cocoa Beans in Nigeria. *Nigerian Journal of Theoretical and Applied Research (NJOTAR)*, I, 104-108.

Adeosun, S.O., **Ilori, M. O.**, and H.A. Ellis (1980): The Electrical Conductance of Some Molten Carboxylate Mixtures. *Thermochemical Act 39*, 125-133.

Adeoti, O., **Ilori, M. O.,** T.O. Oyebisi and L.O. Adekoya (1999): Engineering Design and Economic Evaluation of a Family-sized Biogas project in Nigeria. *Technovation: The International Journal of Technological Innovation. Entrepreneurship and Technology Management,* 20, 103-108.

Adetayo, J. A., Sanni S. A. and **Ilori M. O.**,: Impact of Information Technology on product Marketing. A case of multinational Company in Nigeria. *Technovation. The international Journal of Technology Innovation, Entrepreneurship and Technology Management.* 19, 691-699

Adewusi S.R.A.and **Ilori, M. O.**, (1994): "Nutritional Evaluation of Spent Grains from Sorghum Malt and Maize Grit. Plant Foods for Human Nutrition 46, 41-51.

Aisien A. O. and Ghose B.P. (1978): Preliminary Studies on the Germination Behaviour of Guinea Corn (Sorghum Vulgare). *Journal of Science of Food and Agriculture* 29, 850-852.

Aju, A. (1994): Industrialization and Technological Innovation in an African Economy.Regional Centre for Technology Management.(RECTEM).Lagos.

Akarakiri, J. B., K. A. Yusuf and **Ilori, M. O.** (2000): The Impact of Food and Beverage Multinational Companies on Industrialization in Nigeria. *The Quarterly Journal of Administration.* xxxi, 1&2,73-87.

Akinbami, J.F.K., **Ilori, M. O.**,, A.A. Adeniyi and S.A. Sanni (2001): Improving Energy Use Efficiency in Nigerian's Industrial Sector. A Case Study of Beverage Plant. *Nigerian Journal of Engineering Management.* 1, 1-5.

Akinbami, J.F.K., **Ilori, M. O.**,, T.O. Oyebisi, I.O. Akinwumi and O. Adeoti (2001): Biogas Energy Use in Nigeria: Current Status, Future Prospects and Policy Implications. *Renewable and Sustainable Energy Reviews.* 5, 97-112.

Akinwumi, I. O., **Ilori, M. O.**, and D.A. Asaolu (1996): Some Factors Affecting Vocational Training Giving to Apprentices in the Garment Industry. *Ife PsychologIA,* 4, 1, 156-167.

Akinwunmi, I. O., **Ilori, M. O.**, M.M. Maduekwe and J.B. Akarakiri (2000): An Evaluation of the Impact of the Brewery Wastes on the Brewery Environment in the South Western Nigeria. *Nigerian Journal of Engineering Management*, 1, 1, 33-43.

Alofe, F.V. (1985): The General characteristics and cultivation of some Nigerian Mushrooms. Ph. D. thesis, Obafemi Awolowo University, Ile-Ife, Nigeria.

Araoz, A. "The Revitalization of Technology Research Institutes in Developing Countries". *UNIDO Vienna*, Austria, 1994.

Ariahu C. C. and **Ilori, M. O.**, (1992): Use of Periwinkle as Sources of Dietary Protein The Toxicological, Processing, Nutritional and Policy Implications. *Food Reviews, International,* 8, 223-233.

Bwisa, H. M. (1990): Scientific Cooperation for Development in Africa. *African Development Review,* 2, 1-19.

Cervantes, M. (1999): "Public/Private Partnership in Science and Technology: An Overview". *STI Review* No. 23. OECD. p. 4.

Cock J.H. (1974): Agronomic Potential of Cassava Production. Processing Cassava Processing and Storage. An Interdisciplinary Workshop, Pattaya, Thailand.

Cooper, C. "Science, Technology and Development: The Political Economy of Technical Advance in Under- developed Countries". Frank Cass & Co, Ltd. 1978.

Crawford. C. M. "New Product Failure Rate: Facts and Fallacies". *Research Management* 22 (5): 9-13, 1997.

Drucker P.F. (1970): *Technology Management and Society,* London: Heinemann.

Emovon, E. U. "National Research Policy and Sustainable Development". In, Research *Capacity Building for Sustainable Development in Nigeria,* ed. Adeniyi, P.O., Unilag Consult, Lagos, Nigeria, 1999.

Faborode M. O. (2005). Technology, Life and Living. Ile-Ife: *Obafemi Awolowo University Inaugural Lecture Series 183.* Obafemi Awolowo University Press Ltd.,

Fashakin, J.B., **Ilori, M. O.** ,, I. Olarewaju (1991): Cost and Quality Optimization of a Weaning deity,from Plant Protein and Corn Flour Using Computer Aided Linear Programming Model. *Nigerian food Journal* 9, 123-132.

Fasidi I.O. and Kadiri M. (1990) Effect of Maturity on the Nutritive value of two Nigerian Mushrooms *Tricholoma lobayensis* and *Cortinarius mellions Fries. Nigerian Journal of Botany*; 3, 41-47.

Federal Government of Nigeria (1981): *National Policy on Education (Revised)* Lagos: NERC Press.

Federal Institute of Industrial Research Oshodi (FIIRO)(1976): Malt Production from Local Grains. *FIIRO Technical Bulletin for Industries* 5, 1-4

Federal Ministry of Education (2003): *Education Sector Status Report.* Abuja: Federal Ministry of Education.

Flannigan, B.; Okagbuf, R.N. Khalid, R. and Tesh, C.K. (1982): Mould flora of malt in production and storage. *Brewing and Distilling International* 12, 31-33, 37

Freeman, C. (1987): *Technology Policy and Economic Performance: Lessons from Japan.* London: Pinter Publishers.

Girvan N. Y. (1983): *Carribean Technology Policy for Small Developing Economies, Caribean Research,* Jamica: University of the West Indies.

Guild, P. D. and Bachher, J. S. (1996): "Equity Investment Decision for Technology-based Venture". *Int. J. Technology Management. Special Issue on Technology and Financial Resources for SME Innovation,* 12 (7/8): 787-795.

Hough J. S., Briggs, D.E. and Steven R. (1971): *Malting and Brewing Science,* London: Chapmton and Hall Ltd.

Ilori, M. O. (1983): Chemical Changes occurring in canned *Wara*nkasi – A White Nigerian soft cheese. M. Sc. thesis, Obafemi Awolowo University, Ile-Ife, Nigeria.

Ilori, M. O. (1990): Development and Assessment of Sorghum meat as a Beverage-base in Nigeria. Ph.D. thesis, University of Ibadan, Nigeria.

Ilori, M. O. J.O. Akingbala, F.B. Oguntimehin and J.O. Ogundiwin, (1990): Effect of Grain Bed Thickness, Duration of Stepping and Germination on the Malting Properties of Sorghum: *Libensmittel-Wissenchaft Un-Technologies, (LWT)* 23, 505-512.

Ilori, M. O. , and Oloruniwo, F.O. (1990): Application of Linear Programming Model for the formulation of Beer. *Journal of the Nigerian Institute of Industrial Engineers I* 2, 85-98

Ilori, M. O. (1991): Use of Sorghum Malt for Beer Brewing in Nigeria. Technovation *The International Journal of Technological Innovation, Entrepreneurship and Technology Management* 11, 27-37.

Ilori, M. O. and M.M. Ige (1991): Oilseed Meals as a Potential Solution to Protein Dietary Shortage in Nigeria. Technovation: *The International Journal of Technological Innovation, Entrepreneurship and Technology Management.* 11, 315-322.

Ilori, M. O. , and S.R.A. Adewusi (1991): Effect of Ammonia on the Malting Losses of some Improved Nigeria sorghum Varieties. *Journal of the Institute of Brewing, London,* 97, 111-113.

Ilori, M. O. , J.O. Akingbala (1991): Effect of Formaldehyde Treatment on the Malting Properties of Sorghum. *Nigerian Food Journal,* 9, 167-177.

Ilori, M. O. , and J.O. Akingba (1991): Malting Properties of Some Nigerian Sorghum Varieties. *Ife Journal of Technology,* 3, 1-6.

Ilori, M. O. B. Fessehatzion, J. Ogundiwin, C.O. Babalola and O.A. Olajuyigbe, (1991a): Effect of Malting and Brewing on the Micro-organism Associated with Sorghum Grain and Malt. *Master Brewers Association of the Americas (MBAA) - Technical Quarterly 28, 45-49.*

Ilori, M. O. J.O. Akingbala, F.B. Oguntimehin and J.O. Ogundiwin (1991b): Adaptation of a Conventional Mashing Profile of Barley Malt for Mashing of Sorghum Malt. *Libensmittel Wissenschaft Und-Technologies,* 24, 24-33

Ilori, M. O. J.O. Ogundiwin, S.R.A. Adewusi (1991c) Sorghum malt and brewing with Maize/Sorghum Adjunct. *Brewing and Distilling International (BDI)* 21, 10-13.

Ilori, M. O., (1992): Bibliographic and Policy Review of Technological Development in Food Processing Industries in Nigeria. *Science, Technology and Development, 10, 67-79.*

Ilori, M. O. (1994): The role of Local Government in Technological and Industrial Development in Nigeria. Technovation - *The International Journal of Technological Innovation, Entrepreneurship and Technology Management* 14, 181-195.

. **Ilori, M. O.**, and A. Awoyinka (1994): An Evaluation of Hospital Food-service Management in Nigeria. The Home Economist - *The Journal of the Institute of Home Economists,* 4, 8-10.

Ilori, M. O., and B.O. Solomon (1995): The Activities of Public and Private Sectors in Biotechnological Capability Building in Nigeria. Proceeding of the International Symposium on the Development of Small and Medium Enterprises for Biotechnology Commercialization in Developing Countries. July 24-28,

Ilori, M. O., T.O. Oyebisi and M.L. Nassar (1995): Models of Technology Transfer from Laboratories to the Industry: Relevance and Implications for Developing Countries. *Unilag Journal of Business*, 1, 1-8.

Ilori, M. O., E.O. Makinwa and I.A. Irefin (1996). Indigenous Technological Capability Development in the Brewing Industry in Nigeria: An Engineering Economic Assessment and Policy Implications, *Food Reviews International, 12, 4, 511-523.*

Ilori, M. O.,, S.K. Layokun, A.O. Idowu and B.O. Solomon (1996): Economics of Small Scale Ethanol Production from Breadfruit and Cassava via Plant Enzyme and Acid hydrolysis. *Master Brewers Association of the Americas (MBAA) - Technical Quarterly 33, 38-43.*

Ilori, M. O., and I.A. Irefin (1997): Technology Decision-making in Organizations. Technovation: *The International Journal of Technological Innovation, Entrepreneurship and Technology Management*, 17, 153-160.

Ilori, M. O., I.O. Fasidi and O.S. Ikikhuemhen (1997): Mushroom Research and Commercial Cultivation in Nigeria. Food Reviews International, 13, 389-496.

Ilori, M. O., and I.A. Irefin, (1997a) Development of non-alcoholic beverages from some tropical crops. *Master Brewers Association of the America (MBAA) - Technical Quarterly,* 34, 299-233.

Ilori, M. O., I.A. Irefin and A.A. Adeniyi (1997b): Engineering Economy Studies on the Production of Non-alcoholic Beverages from some tropical crops, *Technovation: The International Journal Technological Innovation, Entrepreneurship and of Technology Management,* 17, 715-721.

Ilori, M. O., A.A. Adeniyi, J.B. Akarakiri and J.A. Adetayo (1998): An Evaluation of Market Potential and Impact of Cultivated Mushroom in Nigeria. *Journal of Rural Development and Economics,* 1.

Ilori, M. O., I.O. Akinwumi, M.M. Maduekwe and A.A. Adeniyi (1999): Environmental Management Strategies Adopted by Some Breweries in the South Western Nigeria. *Master Brewers Association of the Americans (MBAA) Technical Quarterly, Vol. 36, No. 3, 323-327.*

Ilori, M. O., J.S. Oke, S.A. Sanni (2000): Management of New Product Development in Selected Food Companies in Nigeria - *Technovation: The International Journal of Technological Innovation Entrepreneurship and Technology Management*, 20, 333-342.

Ilori, M. O. Adeniyi, A. A., Sanni, S. A., Oyewale A. A. and Irefin I. A. (2002): Developing a Manufacturing Based Economy in Nigeria through Science and Technology. *Technovation,* 22, 51 – 60..

Irefin, I.A. and **Ilori, M. O.**, (1996): Food Standardization Policies in Nigeria. *Food Reviews International 12, 251-270.*

Irefin, I. A., **Ilori, M. O.**, and Solomon, B.O. (2005): Agricultural Biotechnology, R&D Innovations in Nigeria. *International Journal of Agriculture, Resources, Governance and Ecology,* 4,1,64 – 80.

Irefin, I.A., **Ilori, M. O.**,, and B.O. Solomon.(2005): Developing a Biotechnology R & D and Innovation Agenda for Nigeria – Some Critical Management Issues. *Nigerian Journal of Industrial and System Studies, 7, 1-13.*

Jesuleye O.A., Siyanbola W.O., Sanni S.A and **Ilori M.O.** (2006): Energy Demand Analysis of Port-Harcourt Refinery, Nigeria and its Policy Implication. Energy Policy (in Press).

Jinma, C., Gitta, C., Disenso, A., and Bince, A. (2005) Forging New Technology Alliances. *Cooperation South.6, 59-71*

Kwanjai, N. N. (2000): "Applying General Systems Theory to put together NIS Jigsaw-puzzle pieces: a profile of the Thai national innovation system". Paper presented at INTECH-CERES WP.3 Conference. Maastriht.17 May p.13.

Lalkaka, (1999): "New Strategies, Skills and Structures for Technological Innovation". Paper presented at XVI IASP World Conference on Technology Parks. Istanbul. September. p.8.

Lundvall, B. (1992b): "Introduction", in Lundvall, B. (ed) National Systems of Innovation: *Towards a Theory of Innovation and Interactive Learning*.London: Pinters Publishers. pp.1-18.

Lundvall, B. and Johnson, B. (1994): "The Learning Economy". *Journal of Industry Studies*. Vol. 1 No 2.

Metcalfe S.(1995): "The Economic Foundations of Technology Policy: Equilibrium and Evolutionary Perspectives", in Stoneman, P. (ed) *Handbook of the Economics of Innovation and Technological Change*. Oxford: Blackwell Publishers.

NISER (1998): *Survey of Business Conditions*. NISER. Ibadan. pp.5-7.

Nonaka, J. (1994): "A Dynamic Theory of Organizational Knowledge Creation". *Organization Science*. Vol. 5. No. 1 pp. 14-37.

Norris, K. and Vaizey, J. "*The Economic of Research and Technology*". C. Cater (editor) London: George Allen and Unwin Ltd. 1973.

NOTAP (National Office for Technology Acquisition and Promotion). "NOTAP Braces up for Commercialization of Innovations and Research Results". *Newsletter 1: 7. December 1999.*

Oduola, I.A., J.B. Akarakiri, and **Ilori, M. O.** (2005): Organisation, Governance and Networking Practices in Public R & D Organisations in Nigeria. *Quarterly Journal of Administration (accepted for publication).*

Oduola, I.A., J.B. Akarakiri, and **Ilori, M. O.** (2005): Financial Management Practices in Public R & D Organisations in Nigeria. *International Journal of Engineering Management.*

Oduola, I.A., J.B. Akarakiri, and **Ilori, M. O.** (2006): Evaluating Project Management and R & D and Innovation Services Practices. *Ife Social Sciences Review*. In Press.

OECD (1981): North/South Technology Transfer Adjustment Ahead. *Organisation for Economic Co-operation and Development (OECD) Publication pp 17-19*

OECD (1996b): The Knowledge –Based Economy. OECD. Paris.

OECD (1997a): *Diffusing Technology to Industry: Government Policies and Programmes.* OECD. Paris. p. 33.

OECD (1998): University Research in Transition. OECD. Paris.

Ogbimi, F. E. "Commercialization of R&D: Preparing for Commercialization of Scientific Research Results in Nigeria". *Science and Public Policy,* 17: 373-379, 1990.

Ogundiwin, J. O., **Ilori, M. O.** , and M.A. Okeleye (1989): Brewing of Clear Lager Beer from sorghum Grain (SK 5912) Without the Addition of External Enzymes to Achieve Saccharification - A Case study. A Paper Presented at the Symposium on Industrial Utilization of Sorghum: Sponsored by the International Crops Research Institutes for Semi-Arid Tropics (ICRISAT). West African Sorghum Programme, Kano, 4-6, December 1989.

Ogundiwin, J. O.; **Ilori, M. O.** ,, Fessehatzion, B. and C.O. Babalola, A.O. Olajuyigbe (1991): Effect of Chemical Treatments on the Micro-organisms Associated with Malting of Sorghum Grain and Sorghum Malt. *Journal of Applied Bacteriology,* 71, 139-143.

Ogundiwin J. O. and **Ilori, M. O.** , (1991): Development of Stout from Sorghum Malt. Libensmittel Und-Technologies, 24, 185-188.

Ogundiwin, J.O. (1983): Chemical Composition and Nutritive value of *Wara*nkasi (Local Chease) from cow milk. Ph.D thesis, Obafemi Awolowo University, Ile-Ife, Nigeria.

Ogundiwin, J.O. and **Ilori, M. O.** , (1990): Preservation of *Wara*nkasi I: A Suitable Canning Procedure for the Preservation of *Wara*nkasi - a White Nigerian Soft Cheese. *Nigerian Journal of Engineering and Technology, (NJET)* 973-83.

Ojewale, B. A, **Ilori, M. O.** , and T.O. Oyebisi. (2001): Industry-Academic Relation: Utilization of Idle Capacities in the Polytechnics, Universities and Research Organization by Entrepreneurs in Nigeria. *Technovation. The International Journal of Technological Innovation, Entrepreneurship and Technology Management.* 21,695-704.

Okafor N. and Anishe (1980): Brewing a larger beer from Nigerian Sorghum. *Brewing and Distilling International* 10, 32-35.

Oke, J. S., **Ilori, M. O**. and Sanni, S. A. (1999): "New Product Development Motivation and Product Performance in Selected Food Companies in South Western Nigeria". Proceedings of Manufacturing Engineering Conference organized by Nigerian Society of Industrial Engineers, Ibadan Branch. Pp 147-156, Okebukola, P.(2002): The State of University Education in Nigeria. National Universities Commission. Abuja. p.42

Okoh, I. A., G.O. Babalola and **Ilori, M. O.**, (1995): Effect of Methanol Extract of *Vernonia Amygdalin* on Malting and Brewing Properties of Sorghum. *Master Brewers Association of the Americas (MBAA) Technical Quarterly*, 32, 11-14.

Organisation for Economic Cooperation and Development (OECD, 1981): *North South Technology Transfer Adjustment Ahead* pp 17-19

Oyebisi, T. O., **Ilori, M. O.**, and M.L. Nassar (1996), Industry - Academic Relation: An Assessment of the Linkages between a University and Some Enterprises in Nigeria. *Technovation: The International Journal of Technological Innovation, Entrepreneurship and Technology Management* 16, 203-209.

Oyebisi, T. O., B.A. Ojewale, **Ilori, M. O.**, and I.O. Akinwumi (2001): An Evaluation of Exploitable Idle Capacities in Some Polytechnics and Universities and Research Institutes in South Western Nigeria. *Nigerian Journal of Engineering Research and Development.*

Oyebisi, T. O., **Ilori, M. O.**, and C.O. Adedeji (1999): An Assessment of Strategies for the Maintenance of laboratory Equipment at a University in Nigeria. Ife Social Sciences Review. 18, 235-244.

Oyebisi, T.O. **Ilori, M. O.**,, J.B. Akarakiri and O. Adeoti (2000): Locational Analysis of Bio-gas Plant in Nigeria. Energy: *Nigerian Journal of Engineering Management*. 1,3,7-13.

Oyelaran-Oyeyinka, B.(2002): " Manufacturing Response in Systems of Innovation: Evidence from Brewing Firms in Nigeria". UNU/INTECH Discussion Paper No. 2002-3.

Oyelaran-Oyeyinka, B and Barclay, L. A.(2003): " Systems of Innovation and Human Capital in African Development". UNU/INTECH Discussion Paper No. 2003-2.

Oyewale, A. A. (2003): "Evaluation of the Interactions among the Key Elements of Science and Technology Innovation System in Nigeria". Ph.D Thesis, Obafemi Awolowo University, Ile-Ife, Nigeria,

Patel, P. and Pavitt, K. (1994): "The Nature and Economic Importance of National Innovation Systems". STI Review. No.14. OECD. Paris.

Plonski, G. (2000) S&T Innovation and Cooperation in Latin America. Cooperation South 1, 99-107

RMRDC (1992): Investment Profiles for Nigeria. Published by Raw Materials Research and Development Council (RMRDC) Lagos.

Sanni S.A. and **Ilori, M. O.** (1996): Strategic Management of Technology. In *Readings in Technology Management*, edited by S. A., Sanni O.O., Mojola M.O., Ilori and J.B. Akarakiri. National Centre For Technology Management O.A.U. Ile-Ife. ISBN 987-2930-00-8 Pp 43-56.

Sanni, S. A., Ilori, **M. O.**,, A.R. Opaleye and A.A. Oyewale (2001): Nigeria's Technology Policy: Is it Adequate in the Globalizing World? *Technovation, The International Journal of Technological Innovation, Entrepreneurship and Technology Management - 21, 237-243.*

Sanusi, J.O. "Overview of Governments Efforts in the Development of SMEs and the Emergence of Small and Medium Industries Equity Investment Scheme (SMIEIS)". Paper presented at the National Summit on SMIEIS organized by the Bankers' committee and Lagos Chamber of Commerce and Industry (LCCI). Lagos. 2003.

Sasson A. (1994): Biotechnologies in Developing Countries Present and future. World Journal of Microbiology and Biology, 10:127-128.

Senker, J. and Senker, P. (1997): "Implications of Industrial Relationships For Universities: a case study of the U.K. Teaching Company Scheme". *Science and Public Policy. Vol. 24. No. 3. June. pp.173-182.*

Solomon, B. O., S.K. Layokun, A.O. Idowu and **Ilori, M. O.**, (1994) Prospects for the Utilization of the Endogenous Enzymes in sorghum Malt in the Hydrolysis of Starch: Case Study with Utilization of Breadfruit Starch for Ethanol Production. *Food Biotechnology*, 8, 243-255.

Stankiewicz, R. (1986): *Academic and Entrepreneurs: Developing University-Industry Relations*. London: Pinter Publishers.

Stanton, W. J., Etzel, M. J., and Walker, B. J. "*Fundamentals of Marketing*". 10th Ed. New York: McGraw Hill, Inc. 1994

Summentti, D.J. (1981): *Industrial Engineering* 13, 70

Taiwo, K., I.A. Irefin and **Ilori, M. O.**, (1997): Strategies for Integrating Traditional and Modern Food Processing Techniques in Nigeria. *Food Reviews International*, 13, 611-621.

Taiwo, K. A., Oladepo, O. W., **Ilori, M. O**, Alabi, C. T. (2002) A Study of the Nigerian Food Industry and the Impact of Technological Changes on the Small-Scale Food Enterprises. *Food Reviews International* 18, 243-261

Takeuchi, W. J and Nonaka, I. "The New Product Development Game". *Harvard Business R view* 64 (17): 137-146, 1986.

Tiftin. S. (1997) "Building Science and Technology Innovation System in Africa." Paper delivered at the First Regional Workshop on The Restructuring of National Science and Technology System in Africa Regional Program for Technology Management (REPTEM) Lagos; May 12-16, 1997.

Twiss, B. "*Managing Technological Innovation*". 3rd Edition. London: Pitman Publishing 1990.

Ugwu L O., Oyebisi T. O., Ilori M. O., Adagunodo E. R. (2000): Organizational input of Information Technology on the banking and Insurance Sector in Nigeria. Technovation. *The International Journal of Technological Innovation, Entrepreneurship and Technology Management 20, 711-721*

Umoh I.B. and Oke, O.L. (1977): *National Report International* 16, 29.

United Nation Industrial Development Organisation, "UNIDO" (1989): Now Technologies and Global Industrialization. Prospect for Developing Countries prepared by Regional County Studies Branch, Industrial Policy and Perspective Division, V 89-61150.

Valentas, K. J., Levine, L., Clark, J. P. "*Food Processing Operations and Scale-up*". New York: Marcel Dekker Inc. 1990.

WAITRO (1999): "*Best Practices for the Management of Research and Technology Organizations*". Special Report by World Association of Industrial and Technological Research Organizations, Denmark, 1999.

Wallmark, J. T. (1997): "Inventions and Patents at Universities: the case of Chalmers University of Technology". *Technovation*, 17 (3): 127-139.

World Bank (1999): *World Development Report 1998/1999: Knowledge for Development.* New York: Oxford University Press. pp. 16-25.

World Bank (2002): "Results of the Nigerian Firm Survey". www.worldbank.org/rped/documents/rped118.pdf

Xue, L. "Promoting Industrial R&D and Hi-tech Development through Science Parks: The Taiwan Experience and its Implications for Developing Countries". *Int. J. of Technology Management, Special Issue on R&D Management,* 13, 744-761, 1997.

Zadrazil, F. and Dube, H.C. (1992): *Mushroom Research* 1, 25-32.