INNOVATIVE SCIENCE AND TECHNOLOGY FOR RAW MATERIALS' DEVELOPMENT AND UTILIZATION IN NIGERIA: A CHALLENGE FOR INDUSTRIAL DEVELOPMENT

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Preamble

Science and technology together cover the 'gathering and generation of information about the material world and the application of that information for the welfare of mankind'.

Innovation on the other hand is defined as the "technical and marketing process of translating inventive activities into products and processes". In other words, invention is a distinctly different activity from innovation. The relevance of innovative science and technology to national industrial growth and competitiveness in the globalized world is a widely accepted concept. The advanced countries of the world are where they are today primarily because of their ability to use science, technology and innovation as effective tools for achieving their national objectives. These countries have changed the life-styles of their peoples through the cultivation and application of innovative science and technology. The developing countries have fallen behind primarily because of their backwardness in this respect and Nigeria is no exception.

It is now generally realized that the inherent strength of a nation lies in the skills of its people which can be acquired and enhanced through the practice of science and technology in every field. The promotion of scientific knowledge and development of technology, through their increasing application, create the necessary conditions for the socio-economic uplifting of a country. 'Technological progress is thus the crucial determinant in the realization of the twin objectives of eradication of poverty and acceleration of socio-economic development'. Nigeria has been struggling to meet the basic needs of its people, vis-a-vis food, clothing, shelter, health, education and the like, and to substantially raise the living standards throughout the country. In order to achieve these goals and to keep up with the rest of the world, Nigeria, too, must harness science and technology innovation for industrial development which is a veritable tool that will assist the country in achieving the millennium development goals.

Records show that Nigeria has a visible S and T infrastructural network, and conduct R and D in a broad range of fields. However in spite of the fact that government policies seem favorable to S and T, the effect of S and T innovation in Nigeria on industrial growth and productivity has been minimal. This fact has been of considerable concern to the public and private sector and various attempts have been made to improve the situation. For instance, in 1992, the then Minister of Science and Technology (FMST) Professor G.O. Ezekwe declared that research should go into production.

A meeting involving the Federal Ministry of Science and Technology (FMST), an industrial consultant and a local bank interested in financing innovative S and T for industrial development held in Lagos with the sole objective of charting the way forward. Unfortunately, no further progress was made on this initiative after the meeting. The search for solution had even involved some pioneer efforts by the Raw Materials Research and Development Council (RMRDC) in the R and D of local raw materials for industrial production. Details of this will form the core of this paper.

Also this paper will review and outline factors which is militating against achievement of effective S and T innovation in raw materials, development and utilization for industrial growth and articulate roles of RMRDC in Innovative S and T for raw materials, development and utilization in Nigeria.

The S and T innovation concept

Technological innovation is defined as the first commercial application of a new technology. The emergence of a new technology, which may take the form of a product, process or service, is a result of several activities

spanning an appreciable length of time depending on the type of technology. The following phases have been identified as the steps and actions required for taking a project from initiation to commercialization:

i. Idea generation.
ii. Screening of ideas.
iii. Research and Development.
iv. Business analysis.
v. Prototype development.
vi. Test marketing and
vii. Commercialization.

Idea generation

Idea generation involves a search for ideas by such means as brainstorming, attribute listing and need identification. Ideas normally originate either from R and D institutions including universities or from specific market needs. These two sources of new technology ideas had in recent years been described as technology push and market pull respectively that is your concept/idea must be market driven.

Screening of ideas

Whatever the source of the ideas, screening entails evaluating all the ideas with the view of identifying and concentrating on those with greater potential for success.

Research and development

R and D is a part of the process leading to technological innovation. During the R and D phase, the idea on paper is translated into a physical product, process or service. Technological evaluations including laboratory testing are made to establish the production feasibility. Though there is no direct correlation between R and D budgets and such operating results such as profits or turnover, the R and D phase accounted for between 15% and 30% of the total costs of successful innovations. The individual actions that should occur within the research organizations are:

(a) Laboratory scale research
(b) Pilot plant development
(c) Scaling up
(d) Design and engineering of full scale plant
(e) Production trials

Business analysis

The essence of business analysis is to identify product features, estimate market demand and product profitability, and assign responsibility for a further study of the product feasibility.

Prototype development

During prototype development, the laboratory output is scaled up for pilot plant production. Again technical evaluation is carried out to ensure that the pilot product is not significantly different from the laboratory type. For a new product such as food, central location testing (CLT) and house use testing (HUT) are made to establish the production feasibility. In CLT, sample of the new product are tested on consumers picked at random in some convenient locations.

The test is usually performed by an outside agency, and the manufacturer may or may not be identified because of protection. If the test is encouraging, the next usual step is the HUT. Here the samples, prepared and packaged in near-commercial fashion, but often with no commercial identification, are provided for consumers for use in their houses. Their comments obtained through questionnaires and interviews are subjected to statistical analysis (Valentas *et. al.* 1990).

Test marketing

The next stage is to test market the product in a chosen geographical area. Marketing and advertising programmes should be developed simultaneously with the physical product. The first goal of most advertising is to motivate

trials and repeat purchase of a product. A product will not succeed if no one tries it; and no product will survive without repeated trials by consumers. This market tests, in-use tests and other commercial tests are conducted in order to ascertain the feasibility of the full marketing programme. At the test marketing stage, design and production factors may have to be adjusted as a result of test findings. This stage aids the management to decide whether to proceed to full-scale production or abandon the project.

Commercialization

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.

The seven phases in the new product development process has 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 more appropriate in a fiercely competitive business environment where speed and flexibility are critical success factors for innovation. The 'rugby' approach is integrative and overlapping, allowing a multidisciplinary team made up of functional specialists like R and D engineers, production engineers, marketing experts and cost consultants to handle the innovation process from start to finish.

It may be difficult to accurately describe a project as "ready for commercialisation". (The complete cycle of innovation) if it has not gone through the above steps. The marketing of these projects, although very important, was usually under emphasized. Most it more efficient and economical to place this activity in the hands of a marketing countries have found organization such as India's National Research Development Corporation (NRDC), Malaysia's Technology Development Corporation (MTDC) and Australia's Council for Scientific and Industrial Research (CSIR).

Factors militating against innovative science and technology for raw materials development and utilization in Nigeria

The factors militating against innovative science and technology towards the development and utilization of raw materials in Nigeria are numerous. Some of the constraints are discussed below.

Inadequate research orientation

Previous study revealed that research policy is lacking among Research and Training Organisations (RTOs) in Nigeria (Ajoku, 2002). As a result, research planning is not systematically carried out, and research priorities and targets are not usually clearly defined. Proposed projects are usually not adequately evaluated for desirability, while many projects are based on the personal initiatives of the research staff. The FMI report (1996) found that new projects were initiated largely from within the R and D organizations as follows:

Initiator of projects	**% of total**
Individual researcher	44.0
Research coordinating team	18.0
Directors of research	15.0
End users	9.7
Government directives	7.0
Chairman of boards of research institutes	0.3
Others	6.0
Grand total	**100**

This observation highlights the non-systematic approach to the idea generation and screening stages of R and D earlier discussed. A situation where 75% or more of research projects arise from within the R and D institution is definitely not demand driven and therefore may affect the adoption of the research outputs.

Non-availability of Information on commercializable inventions and R and D results

Several commercializable inventions and research results have been generated by educational institutions and research institutes in Nigeria, but regrettably, one of the main reasons given for their low utilization by industrial firms was that industries were not aware of these inventions and results (Oyewale, 2003).

In order to address this information gap, the National Centre for Technology Management (NACETEM) was commissioned in 1994 to develop a database on these inventions and research results. The National Office for Technology Acquisition and Promotion (NOTAP) was also later mandated to collate findings, patent them, and provide funds and relevant complementary information for their commercialization (NOTAP, 1999). The publication of the FMST on the profiles of some of these inventions/research results (Aliyu, 2004) is also a bold step aimed at filling the gap. While this step is commendable, the deficiency in managing the information generated had prevented the achievement of the desired results in commercialisation. Furthermore, the overlap of mandate between government organs had limited the level of commitment to the project.

Poor technological entrepreneurial culture

Technological entrepreneurial culture is the training of the mind for the urge to commercialize inventions that are based on technological R and D. When developed in a country, the culture encourages students, researchers and industrialists to exploit research results. This culture is not adequately developed in Nigeria; therefore in order to promote the entrepreneurial culture, many tertiary educational institutions in Nigeria are trying to introduce entrepreneurship studies into their curricular.

Inadequate infrastructure

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. Economic infrastructure includes power, telecommunications, water supply, sanitation sewage, waste disposal, and transportation services among others.

Infrastructural facilities are intermediate inputs into production, and their costs have direct effects on firms' products, competitiveness and profitability. Unfortunately they are grossly inadequate in Nigeria, and they constitute one of the greatest constraints to small and medium enterprises in taking up R and D results for commercialization. Sanusi (2003), citing a World Bank study, indicated that such costs accounted for 15 to 20 percent of the cost of establishing manufacturing enterprises in Nigeria.

Inadequate motivation for the commercialization of inventions/research results

As a result of the fear of the unknown, researchers in Nigeria are usually cautious about embarking on activities that would take them out of their institutions/institutes because this might lead to loss of their job. However, the tacit nature of the inventions may require the inventors to work closely with the industrial firms that are exploiting the inventions in some instances. The current conditions of service do not allow the researcher to take up such appointments. Therefore, researchers could be motivated if the conditions of their employment are modified to allow them nurture such projects outside their institutions/institutes for a period, and later return to their jobs.

Wallmark (1997), found that professors produced about 60%, postgraduate about 33% and undergraduate students about 7%, of the inventions generated in Chalmers Univesity of Technology in Sweden. To enable researchers undertake this type of 'leave', Japan in 1997 amended her retirement laws for the academics (OECD, 1998a). Having similar policies on nurturing spin-off companies by researchers outside their institutions/institutes if they so desire, would encourage Nigerian scientists to venture into commercializing their inventions, and at the same time, reduce the risks faced by the prospective academic entrepreneurs. Spin-offs or start-ups as they are sometimes called are firms that are specifically established to exploit technologies and research findings that originate in their parent organizations.

Lack of funding and efficient funding structure for innovation

The rapid decline in funding of RTOs in both developing and developed countries is affecting research orientation. Traditionally, these institutions were set up to assist in industrial development and were fully supported with government funding. Many years of stagnation and un-productivity has resulted in continued reduction in government funding. It has been observed that RTOs that received more than half of their money directly from industry become industry focused (WAITRO, 1999). They conduct work that is respected and valued by industry and industry will support their continued existence. On the other hand, those that receive more than half of their money from government without any mechanism whereby industry directs or influences the work conducted are not valued by industry. This scenario explains why RTOs in developing countries cannot

relate their activities with industries. Even when RTOs conduct research that could be relevant to industry, their findings are not considered to be of importance since the research had no industry support.

Most research institutes assert that funds provided by government are inadequate for their operations. However, staff emoluments and other charges take up a high proportion of those funds, leaving only a small percentage for R and D efforts, which are sometimes duplication of projects already executed by other research institutes/institutions. This has a negative effect on the quality of research outputs because most of the work is incomplete, as they do not follow the complete steps of the innovation model.

A number of statements, recommendations and decisions have been made regarding desirable levels of funding for research organizations. For example the OAU Lagos Plan of Action for the Economic Development of Africa (1980) says that at least 1% of each country's GDP should be devoted to R and D. Nigeria's Science Policy document stipulates that funds for S and T should include 2.5%-5.0% of the Federal Budget. In addition, funds from the National Science and Technology Fund (NSTF), international, and other sources could also be used for S and T development. However, 18 years after the launching of the Science Policy, the level of funding is still well below the amounts stated, and the effectiveness of the NSTF is questionable. In order to improve the level of funding and quality of research outputs, R and D institutes/institutions should strive to attract funds from industries and make their projects relevant to the industry.

Furthermore, developing new products is a risky business endeavour because a technically feasible invention might not be economically profitable, and the product may not survive the commercialization process. Cooper (1983) and Crawford (1987) reported that success rates for new inventions ranged from 1% to 85%. The high rate of failure of products in the innovation process discourages commercial banks from financing R and D in the early stages of innovation. Most banks wait till the phase of production or pre-production before they provide financial support. Therefore, commercialization of R and D findings 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 that is offered to new, unlisted, high-risk, high-tech spin-off firms. Guild and Bachler (1996) identified three classes of Venture Capital Organizations (VCOs). These are Private Venture Capital Companies (PVCCs), Public Venture Capital Funds (PVCFs) and Business Angels (BAs). The PVCCs 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 informal, individual investors. The VCOs usually groom spin-off firms into large companies. As the business becomes well established, the VCOs offer their shares for sale at the Stock Exchange to several shareholders. This ensures the survival and sustainability of the company beyond the lifetime of the initial founder and owner. The only existing VCO in the country is the National Risk Fund. Therefore Nigeria should therefore establish more VCOs to support the commercialisation stages of the innovation process.

Inadequate patent education and ineffective 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. The level of patent education among Nigerian researchers is low, as most of them are not aware of what patent entails. Although 90% of the researchers studied by Oyewale (2003) claimed to have commercialisable inventions, only 20% of the institutional respondents have patented some of their inventions.

The patent process also protects the technologies being commercialised from imitators, who may intend to produce counterfeit products. Unfortunately, such imitation products pervade Nigerian market today. The law enforcement units of government should be empowered to combat the production and distribution of fake and illegally produced items in the country.

Absence of effective linkage between research organizations and industry

The 'Local industrial sector' is often made up of small production units many of which cannot undertake R and D. In view of this, there is a wide belief that R and D can only be carried out by large enterprises such as the multinational companies. Furthermore, the absence of effective linkage of research with production also explains to a significant extent, the inability of R and D organizations in Nigeria to commercialize their viable research results. However, recent developments in industrial economies show that SMEs are R and D driven. Nnadi (2000) suggested that appropriate linkages should be forged between researchers and industrial or commercial establishments in order to exploit valuable research results. Such linkages would be in form of involving the industrial sector in formulating the research agenda and projects of the R and D organizations, providing financial support to prosecute the innovation process, and providing staff exchange programmes between the industry and

R and D organizations to facilitate cross-flow of ideas and expertise. The linkage would also help to solve some of the technological problems encountered by the SMEs.

Preference for foreign technology

The domestic industries' lack of interest in the research outputs of Nigerian R and D organizations has been associated with the strong preference for foreign technologies. The foreign-based multinational companies do not have confidence in the quality of personnel and research outputs of the Nigerian R and D organizations and this affects the rate of adoption of the research outputs. On the part of indigenously owned industries, the level of appreciation and response to the issue of collaboration with RTOs 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).

In order to improve the linkages, the R and D organizations should improve the quality of R and D outputs and the quality of research staff. Adequate training, motivation and the exposure of researchers to industrial work environments would greatly improve the staff quality. The quality of R and D outputs could be improved through the aforementioned involvement of the industry in the formulation of research agenda/projects of the R and D organizations, adequate funding, and the provision of R and D facilities/equipment.

The role of RMRDC in innovative science and technology for raw materials, development and utilization

Preamble

One of the primary goals establishing the RMRDC is to use the facilities of the Council to encourage the growth of innovative science and technology for raw materials development and utilization of the country.

This mandate arose as a result of the effects of the Federal Government's National Development Plan of 1975-80 which encouraged industrial expansion through the establishment of large scale capital intensive industries. This expansion resulted in a rise of the country's import bill for raw materials from ₦259.7m in 1977 to ₦7266m in 1986. In 1987, about 55.5% of the nation's foreign exchange was allocated to the importation of raw materials. Again, the global economic recession of the 1980s hit Nigeria's industrial sector so hard that virtually all-industrial groups recorded substantial decrease in output. Capacity utilization in this sector remained largely below 40%. The government intervened by streamlining industries to only those capable of developing raw materials locally through maximizing value-addition and establishing R and D Units for product quality improvement and increase in utilization of local inputs. However, not much information was available on R and D's carried out in the country and locally available resources that could serve as industrial raw materials.

To bridge this gap, the Council between 1988 and 2006 has carried out a number of national surveys on the status of Research and Development (R and D) with a view to identifying the state of research and problems militating against the utilization of research products in the development of our national economy.

It was noted from these studies that, there is a significant gap between researchers, inventors and investors in the country. This accounted for non utilization of research results by end-users. The studies therefore recommended the establishment of a strong linkage between research centres and industries in order to ensure meaningful use of R and D efforts to address our national needs. Furthermore, it identified the need to galvanize the various activities of our researchers into a national goal.

The industries, however, continued to work independently of the research institutes and source their raw materials from outside the country with its attendant foreign exchange drain. The low utilization of research findings was traced to:

(i) the considerable gap between research Institutes and the industries – the potential users of research findings'.
(ii) the risk involved in moving a research result from the laboratory to the industry as well as the huge financial involvement and long gestational period involved.

Therefore, the Council in 1990 embarked on the bold initiative through its national research and development programme to bear this initial risk with the purpose of promoting innovative and applied research necessary for the advancement of local raw materials development and utilization by the manufacturing sector.

The first step taken by the Council towards achieving this objective was by initiating a biennial Techno-Economic Survey into the ten (10) industrial sectors of the Manufacturers Association of Nigeria (MAN). Through this survey, the Council was able to identify themes and sub-themes in all the ten industrial sectors.

Apart from these, the Council also interacts directly with the members of the Manufacturers' Association of Nigeria (MAN) by attending sub sectorial meetings of MAN and through collaborative organization of seminars and workshops where the problems of raw materials availability to the industries are deeply discussed and analyzed.

Consequently, the Council usually commission the national research institutes and individuals to submit comprehensive research and development projects that could address the problems identified through the sources outlined above. It is noteworthy that by the edit establishing the Council, it does not have a laboratory of its own.

In general, the Council has funded implant R and D that concentrates in the following areas to ensure sustainable development of locally available raw materials into industrial inputs:

i. Search for alternative raw materials or substitutes to imported ones;
ii. Development of alternative consumer products to reduce import dependency;
iii. Development of intermediate raw materials for use by local industries and for the export
iv. Development of adaptable process technology and equipment or upgrading of industrial technology or equipment.

Since 1990, the Council has so far sponsored more than 114 R and D projects. Several projects have been successfully completed and already implanted in industries, while others are at different stages of completion.

On completion of the R and D projects, research personnels or teams are usually requested to submit quantifiable products obtained from the laboratory studies for industrial acceptability tests. For instance, in 1993, the Council sponsored researchers at the Department of chemistry, Ahmadu Bello University, Zaria to produce Dehydrated Castor Oil (DCO) from local castor seeds for alkyd resin production. On completion of the study, samples of DCO produced was sent to Nycil Nigeria Limited to ascertain whether it meets industrial specifications of imported DCO being used for alkyd resin production. On confirmation of the suitability test, the Council then upgraded the R and D project to Pilot scale level as the first step towards its commercialization. The plant is located at Kaduna

A recent one was on Brown Sugar Technology in collaboration with National Office for Technology Acquisition and promotion (NOTAP), a technology developed by Nigeria Cereal Research Institute (NCRI) Badeggi.

Value addition and the development of alternative for imported raw materials:

The Council embarked on programmes and projects that are aimed at adding value to some of the nation's resources and also develop alternatives to imported raw materials through R and D activities. These are all aimed at redirecting research focus in research institutes, universities and polytechnics towards key resource-based projects of industrial relèvance. It also attempts to encourage industrial patronage of R and D products from the Research Institutes and Universities through linkages and promotion of viable research findings.

The overall intention of the Council in carrying out specific interventions is to fund industry demand-driven and result oriented R and Ds in areas of need that would produce useable and sustainable raw materials for use by the country's industries. It is aimed at import substitution where locally produced raw materials replace imported once in order to conserve foreign exchange.

Specific interventions

Castor oil project

Nigeria imports 137 tonnes of castor oil at the cost of $6.2 m. Local demand is expected to use 10,340 tonnes in a few years from now. Castor seed plant grow widely in the savannah and semi-arid zones of Nigeria but the potentials remain untapped.

In order to tap this great potential, the Council carried out R and D on castor seed to determine its quality and quantity of oil that can be produced from it. It also developed dehydrated castor oil from the local castor seeds, (ABU, Zaria). This was scaled up to a pilot level and the plant produces 5 tonnes of castor oil per day. This serves the cosmetics, pharmaceuticals, textiles, paints and allied product industries. The product of the plant was purchased by Morrison Nigeria Limited.

The ultimate goal is to produce enough castor seed oil to serve the various industrial needs and put an end to importation. This plant has catalyzed the establishment of a commercial plant of 45 metric tons/day in the Federal Capital Territory (FCT)

Glazier putty and alkyd resin from rubber seed

Oil

Nigeria has large plantations of rubber seed plant and about 42,980 tonnes of seed is wasted annually. The seed contains 40% semi-drying oil used for soap, alkyd resin and painting ink. The Council sponsored an R and D at the Rubber Research Institute of Nigeria (RRIN) and the University of Benin. The researchers found that the level of unsaturation in rubber seed oil is comparable to linseed oil. Linseed oil is being imported for the production of alkyd resin used in surface coating in paints. The research team has produced acceptable alkyd resin used in the manufacture of dark-coloured paints. Further improvement is being carried out on the alkyd resin to make it useful for light coloured paints.

Rubber seed oil is also used for glazier putty production and a local engineering company has designed and fabricated the main equipment which is the putty mixer. The resulting putty has been found to be acceptable for industrial use and feasibility is being carried out to determine the project's viability. Once this is complete, the industries will commence full use of rubber seed oil produced glazier putty and alkyd resin in place of the imported ones from linseed oil.

Organo-mineral fertilizer development

With the current thrust on sustainable agriculture and organic farming, the use of natural produce as fertilizers has assumed greater practical significance; for environmentally safe agricultural development. They are bio-degradable, cheap and quite abundant in all parts of Nigeria.

It had been reported that most Nigerian soils especially soils of the humid lowlands are low in organized matter and therefore have poor ion exchange and better capacities which consequently predispose them to a rapid loss in fertility.

In organic fertilizers have become very costly and scarce and non-available to farmers chemical fertilizer elements such as kaolin and phosphate are being imported in large volumes. All these facts prompted the idea of evolving a soil nutrient management strategy that would ensure optimum utilization of local sourced raw materials.

In line with the mandates of the Council to sponsor research and development projects that emphasize local contents, the Council is presently sponsoring organo mineral based projects, e.g. a study on the mineralization of wastes from palm kernel processing and their transformation into mineralized organic fertilizers.

This project utilizes the De-oiled cake (DOC) which is a by product of from oil refining using palm kernel. The DOC contains some levels of fertilizers elements such as nitrogen, phosphorous, potash and calcium. The short falls in the nutrient contents of the DOC is made up through mineralization using the required elements and ratios NPK 15: 15: 15: and NPK 20: 10: 10 has been produced and tried out in the field on crops

Increasing the efficiency of nitrogenous fertilizer through the use of neem seeds

This project exploited the potential of Neem Kernels powder as nitrification inhibitor, to increase the efficiency of urea. Nitrogen is one of the major nutrients required by plants for successful and sustainable crop production. In many developing countries, Nigeria, inclusive, there is an increasing deficit of Nitrogen. It was estimated that 20-70 kg nitrogen per hectare are being imported yearly in developing countries. The Project has been successfully completed and awaiting popularization and commercialization.

Production of furfural urea fertilizer from maize cob

The project was meant to produce modified urea fertilizer (furfural urea), from maize cob, which would not be as soluble as ordinary urea fertilizer.

Produce some metal-ion furfural urea complexes (zinc-furfural urea), particularly for that need trace amounts of micro-nutrients for optimal growth. The furfural urea fertilizer has been produced and tested out in the field and laboratories. It is going to be scaled up to the commercial stage after proper investigations.

The Council funded an R and D project in the University of Ibadan for the development of fertilizer formulations from organic wastes with mineral supplementation. This was done to remove the constraints of imported fertilizer supply and the need for organic fertilizer in the country.

The Council collaborated with the University of Ibadan to establish a pilot plant for its production to be domiciled in the University of Ibadan at the end of the successful R and D. The result showed that good quality fertilizer could be produced from organic materials for use by fertilizer using industries as well boost agricultural raw materials for sustainable supply to the industries.

Sorghum malting

The use of Sorghum grain as a substitute for imported barley by the Breweries was pioneered by the effort of RMRDC. The Council conducted studies on the replacement of the imported barley for the production of beer with our local sorghum. This informed the Federal Government's ban on barley importation in order to encourage inward sourcing and development of sorghum, which has led to the continued growth of the sorghum grain business, generating employment opportunities, conserving foreign exchange that could have otherwise gone into importation.

Development/sourcing of industrial enzymes from micro organisms

Enzymes which are highly specialized proteins with catalytic activities have become important in medicine, chemical industry, food processing, agriculture and even every day activities in the home. Scientists have been exploring extreme environments in search of enzymes with properties more in tune with industrial needs. These enzymes include; carbohydrases, proteases, peptidases, lipases and esterases, oxidoreductases, lyases and transferases.

Industrial applications for enzymes are divided into the following sectors:

(a) Food and animal feed,
(b) Detergents/cleaners,
(c) Textiles, leather and fur,
(d) Pulp and paper,
(e) Chemicals manufacture.

In the food and animal feed sector, leading applications are in the manufacture of starch-derived syrups, alcoholic beverages, dairy products and animal feed. Enzymes are also used in baked goods, fruit and vegetable processing, protein processing and vegetable oil extraction. Enzymes are used in textile industries to process cotton and cellulosic textiles and also for processing leather and fur.

In Nigeria, most of the enzymes used by the industries are imported. Considering the enormous amount of foreign exchange used in the importation of industrial enzymes and the consequent effect on the products, the local production of industrial enzymes in commercial quantity will go a long way to improve our economy.

In order to explore this huge market and utilize the abundant agricultural raw materials in the country, the Council embarked on sponsoring some projects aimed at producing enzymes for industrial use.

Production of α-amylase in brewing

The pilot production of the important enzyme generated from the output/waste of soughum malting was introduced into the production of Beer. The project carried out in collaboration with International Breweries Ilesha. Along side, the council is sponsoring other R and D projects in enzyme production and utilization includes:

- Production of α and β Amylases from Aspergillus Niger from agricultural waste.
- Production of Baker's yeast and Industrial Enzyme from Indigenous yeast strains

It is noteworthy that one of the strains of yeast that has been identified was added advantage of diverse sugar utilization and higher gas production. The enhanced gas production would eliminate the use of some additives such as bromate (that has been implicated in causing cancer).

- Production of lyophilized hydrolytic enzymes for industrial use

Development of industrial production of thaumatin *(Thaumatococcus danielli)*. extraction, purification and product development facility

It is so wonderful that the rhizome/fruit of a common Nigerian plant (moi- moi leaf plant) may help safely satisfy the sweet tooth of diabetics and those watching their waistlines. It is also claim that it can help to introduce good sleep (sedative), free bowel movement (laxative) and cure cough (expectorant).

Thaumatin is the sweetest substance known to man at approximately 2000-3000 times sweeter than sucrose. It is completely digested by man and animal, which together with its 'normal' amino acid sequence accounts for its acceptance by regulatory authorities around the world as a safe, natural substance. Thuamatin already is reportedly being marketed as a nutritional supplement in blood sugar stabilizers for childhood behavioural

problems and the more than 3.5 million sufferers from attention deficit disorder. To date, thaumatin is the only commercially available 'natural protein' sweetener. This versatile ingredient has a wide range of applications in foods and drinks and particularly in the field of taste modification and flavour enhancement. The economic potential use of sweetener in the food and drug industries has attracted scientific examination. The project is aimed at developing cheap and efficient extraction and purification process for thaumatin. This is to facilitate thaumatin formulation for commercial and house-hold applications as sweeteners and/or flavour enhancer for drinks, food and medicinal products.

Sectoral intervention with implant R and D

1. Automotive sector

The automotive sector occupies a central place within the industrial sector and has been the vehicle to economic growth in some countries. However, in Nigeria, it has been most affected by low capacity utilization and lower level of local content. The industry suffered a fall from 90% in 1981 to 10% in 2004 in automotive assembly and 40% in component manufacture. One of the major causes of this decline is the fact that the local content in raw materials utilization is quite low and R and D is mostly done in the home countries of the parents assembly companies.

In order to arrest this decline the Council, as its contribution to the auto-sector embarked on some R and D projects such as development of brake-pads from saw-dust and development of car body parts such as bumpers, fenders etc from fibre and resins of local plant and seed oils respectively.

The concrete benefits to be derived from these projects include;

(i) Conservation of foreign exchange,
(ii) Employment generation,
(iii) Transforming of technological know-how.

So far the brake-pads developed are undergoing industrial tests.

2. Developing local raw materials for the paint industry

One of the vibrant and productive sectors of manufacturing in Nigeria is the paint industry. However, the industry is heavily dependent on import of its essential raw materials. The Council took a bold step in reversing this trend by sponsoring some R and D projects.

i. Developing calcined kaolin as substitute to titanium dioxide in paint manufacturing

Titaniun dioxide is extensively used in the paint industry to provide whiteness, brightness and opacity. It is estimated that Nigeria imports 5,000 metric tones of Titanium dioxide annually at a cost of 2,000 dollars per ton. Whilst Local efforts to produce Titanuim dioxide from Ilmenite have not yielded much success, the Council embarked on this project to develop alternative by possibly using calcined kaolin to replace titanium dioxide. The results showed that calcined kaolin extends titanium dioxide in paint and promotes film integrity, cover power, durability flow and leveling and also control gloss. It is noteworthy that calcined kaolin which sells at about USD320 per ton will not only bring down the cost of production of paint but will save the country the colossal amount of money spent on importation of titatnium dioxide and also serve as a source of foreign exchange.

The above development complements the result obtained from the alkyd resin produced from Rubber Seed oil as substitute to the linseed oil imported for paint manufacture.

3. Upgrading nigerian iron ore as raw material for the steel industry

Nigeria is richly endowed with Iron or in excess of 2.5 billion tons, out of which about 750 million tons is amenable to conventional beneficiation techniques. It is known that the Agbaja Iron ore deposit of over one billion tons is high in phosphorous and sulphur, and finelly disseminated, thereby un-amenable to simple beneficiation to serve as feed stock to the country's steel industries. Before the Delta Steel Company was shut down in 1996, Nigeria imports iron ore concentrates from Brazil and Siera Leone. Nigeria currently imports 1.2 million tones of hot rolled and cold products per annum amounting to millions of dollars in foreign exchange.

In order to meet the challenges of importation and target surplus for export, the Council commissioned a research on Agbaja Iron Ore Deposit.

4. Textile industry

With the restriction on imported textile materials, the need to look inwards for production is critical. The Council is involved in some R and D intervention in this area.

i. Production of protoype small scale automated weaving loom

Textile industry is a large employer of labour. Nigeria is engaged in the production of traditional handwoven fabrics for special needs. Studies revealed that productivity is very low and there has not been any local effort to fabricate the textile machinery and component parts in the country. Currently, over 70 million dollars is being spent in importing such special fabrics (damasks, etc) and machinery into Nigeria from asia and Europe.

Fabrics such as *Aso-Oke* are produced using hand looms, which apart form low productivity gives no room for complex design and patterning. The project is an attempt aimed at upgrading indigenous technologies, to facilitate efficient and rapid production of special fabrics based on local resources to meet the ever increasing demand for local fabrics e.g. Aso-oke for which the country would be saved enormous amount of foreign exchange.

ii. Development of long staple cotton for high quality textile manufacturing

Cotton lint, being the most popular apparel because of its comfort qualities, accounts for more than 70 per cent of raw materials input to the textile industry. The short and medium staple length varieties, which account for about 90 percent of the national cotton production, are commonly grown in the country. There is very limited production of long staple cotton in Nigeria probably because of unfavourable climatic or weather conditions. Almost all the long staple cotton consumed by Nigerian Textile mills are imported. The Council in collaboration with Institute of Agricultural Research, Ahmadu Bello University, Zaria developed long staple cotton fibre in Nigeria. Field trials were carried out and the seeds produced are also being boosted.

iii. Development of sericulture

This is a rural-based poverty alleviation project designed to involve rural people in the farming of mulberry plants required as raw materials for silk development. Currently, the project has a total land area of 5.0 hectares of mulberry plantations and about 50 farmers are being trained to commence establishing their own mulberry farm. The project is being implemented in collaboration with the Ekiti State Government and private entrepreneur.

5. Production of wood seasoning kiln for the wood and wood products sector

The wood seasoning kiln is an enclosed environment where temperature and humidity are regulated to achieve the controlled extraction of moisture from timber. It is an essential capital equipment (requirement) in the organized wood products industry.

The international wood products market insists on seasoned wood as the primary material for all wood products. All countries competing in the market must therefore acquire and operate wood seasoning technology. Our fast expanding domestic consumption of wood products is now demanding seasoned wood products at a volume that now supports an expanding market for imported wood products. There is however a severe shortage of wood seasoning capability in Nigeria. Even the limited capability is due entirely to foreign made wood seasoning kilns. Our share of the international wood products market is consequently insignificant.

Wood seasoning technology provides the tool for controlled extraction of moisture from timber. In general, during seasoning, timber is stacked in a hermetically sealed enclosure. Fluid (steam, hot air etc) at regulated temperatures, humidity and speed is driven or cycled through the stack of timber until the resident moisture is vaporized and transported away.

The project seeks to enlarge the wood seasoning capability in Nigeria; popularize the use of Wood Seasoning Kiln in the wood products sector; increase Nigeria's share of the international wood products market; increase Nigeria's share of the international wood products market; Domesticate the technology for the production of wood seasoning kiln in Nigeria.

The Nigeria, wood products sector has the potential of a major export market that is presently under-exploited. The international wood products market insists on and demands seasoned wood as the primary material for all its wood products. Seasoned wood will enhance Nigeria's competitiveness in the international wood products market. Widespread availability of seasoned wood will multiply the use of structurally reliable wood component in industrial applications and the building construction sector.

This project is conceived to provide affordable, cost effective wood seasoning technology that is easily accessible to the Nigerian wood worker; complete with the attendant benefits to the SME and the Nigerian economy.

In the course of the project, wood seasoning kiln types A and B have been constructed. Kiln type A operates on seasoning by condensation while Kiln Type B is designed to operate on seasoning by hot air convention.

6. Chemical and pharmaceutical sector

Industrialization in Nigeria is in a state of chaos. The chemicals and pharmaceutical sector which depends heavily on petrochemicals, solid mineral and agricultural products is no exception.

About 90% of the raw materials in the sector is still being imported and at an enormous cost too. For example, the cost of importation of caustic soda in 2001 was estimated at about and 300,00. Also, the demand of the raw materials has not been met with shortfalls in some cases being over 60% indicating clear lack of local resources utilization. This means that R and D in the development of locally available raw materials has remained very low.

The development and utilization of these raw materials into intermediates for the industries in the sector would help the country save foreign exchange.

i. Utilizing local plants for medicinal and pharmaceutical applications

From results of surveys carried out, it has been confirmed that the Nigeria flora has great pharmaceutical potentials. A comprehensive research and development through the scientific evaluation of these plants, with a view to determining their harmlessness or otherwise and optimizing their utilization for therapeutic purpose is imperative. Efforts are on-going in collaboration with stakeholders for utilization of local flora for pharmaceutical, in the treatment of the diseases fast becoming pandemic in our society like HIV/AIDS, malaria and even Diabetics and hypertension.

Implant R and D is ongoing at the Nigerian Institute of Pharmaceutical Research Idu, Abuja and the Nigeria Medicine Development Agency, Victoria Island, Lagos.

ii. Evaluation of medicinal role of locally produced carbon black

Carbon black (220) is a petrochemical derivative produced by the Nigerian National Petroleum Corporation (NNPC). It is mainly to improve toughness in rubber production. Of recent, it was discovered that it can also be used as an alternative to activated charcoal (Ultra carbon or medical) which is imported. Activated charcoal is used in the management of poison and drug overdose. Carbon black as a petrochemical derivative has a growing market in Nigeria. NNPC furnace black plant using Phillips Technology went into production with a projected annual capacity of 18,000 tonnes.

The present work evaluates the capacity of our locally produced carbon black (₦220 in binding various potential poisons with a view of finding a medicinal or pharmaceutical role of carbon black in poison management. This will conserve foreign exchange expended on the importation of Ultra carbon or medicoal.

iii. Production of cellulose from agricultural waste for pharmaceuticals

Enormous amounts of wastes are generated during the early stages of processing several tropical agricultural crops following harvesting. Cellulose, the world's most abundant chemical compound of plant origin constitutes as much as 50% of the 10 million metric tons of agricultural wastes generated yearly in Africa from four crops – maize, rice, groundnut and sugar cane. This work sought to device and concretize a technology for the extraction of high quality low-cost cellulose from four "useless" agricultural wastes-maize cobs, rice hust, groundnut shell and bagasse sugar cane fibre – for use primarily as excipients in the pharmaceutical industries.

The cellulose will also find ready application in chemical, adhesive, bakery, food and even electrical component industries.

The cellulose from this work costs approximately 25-30% of the imported brands and this will cut down on the costs of tablet production as well as factory machinery, space and overheads. It is also obvious that the work has socio-economic and environmental impact.

7. Vegetable oil sector

In an effort to utilize the abundant oil seeds, which grow uncultivated in various parts of the country, RMRDC embarked on funding R and D into some of these oil plants and seeds. The aim is to enhance their use in nutritional and industrial applications.

Some of the oil seeds projects under RMRDC sponsorship include,

(i) Assessment of seed oils from non conventional sources for nutritional purposes and alkyd resin synthesis,
(ii) Utilization of the by-products of oil palm refining,
(iii) Extraction and evaluation of calabash seed oils and possible use of the lipid-free extract as animal feed,
(iv) Production of carotene concentrate from crude palm oil,
(v) Isolation of tartaric acid from tamaricus indica,
(vi) The debitterization of neem oil and cake and
(vii) Benniseed oil extraction.

Products from these projects are for use in pharmaceutical, paint, food and cosmetics industries and also in agriculture as fertilizers and animal feeds.

These projects are determined to achieve the following objectives:

- to develop a process technology for the extraction of oil and cake for industrial, agricultural and industrial applications.
- to popularize the use of products from these oil seeds in the manufacture of house care products, drugs, paint, animal feeds, fertilizers etc
- to standardize oil and cake from these seeds using standard methods
- to reduce the importation of oil seeds products (e.g. alkyd resins etc.) into the country.

i. The de-bitterisation of neem seed oil and cake

Neem (*Azadiricta indica*) is a tropical tree, which abounds everywhere in Nigeria and mostly in the north. Several parts of the plant are known to have extensive medicinal applications. This wonderful tree contains a vast variety of biological active compounds, which are chemically diverse and structurally complex. Such complex constituents of neem are divided into two major categories viz: isoprenoids and nonisoprenoids. The bitterness of neem products is attributed to limonoids, which are present in amounts of less than 0.001 to 0.1%.

The different products of neem mostly oil and cake can be utilized for a variety of purposes in the health, industrial and agricultural sectors. The cake from seeds after oil extraction is a good source of nutrients (crude protein: 35-38%, ether extract: 4.5-5.5%, crude fibre: 12-15%, calcium: 0.75%, phosphorus: 0.45%). The cake despite its nutritional values is toxic and bitter to taste owing to terprenoids, which restricts its safe inclusion or use in livestock diet. Rather it is widely utilized as a fertilizer and for crop protection.

Despite the abundance of this important economic tree in the country, little or nothing is available to show in terms of exploitation of this tree for the benefit of the populace and generating employment. In other countries especially India, many house care products (soap, toothpaste, creams, cooking oil, livestock feeds, drugs etc.) are now being formulated from neem products. Their agricultural sector has been completely turned around by using neem-based products (fertilizer, pesticide, etc).

This project is determined to achieve the following objectives:

- to develop a process technology for debitterization of neem oil and cake for use as cooking oil and animal feed,
- the process technology to be developed will be simple, cheap, affordable and adaptable,
- to popularize the use of neem products in the manufacture of house care products, drugs etc,
- to standardize the debitterized oil and cake using standard methods,
- to carryout toxicological evaluation of the neem products since they are meant for human and animal consumption.

The expected quality of debitterized neem oil and cake will compare favourably with existing vegetable oils imported into the country and conventional animal feeds from soybeans and groundnuts.

ii. Assessment of seed oils from non-conventional sources for nutritional purposes and alkyd resin synthesis

Studies on seeds from a variety of plants, which grow uncultivated in the Northeastern Nigeria, indicated that they are potential sources of oils for nutritional and industrial applications. These include seeds from *Hematostaphis barteri*, *Balanites aegytiaca*, *Ximenia Americana*, and *Lophira lanceolata*. Preliminary analyses have shown that some of the oils may contain significant levels of unsaturated fatty acids, which are useful

nutritionally and as precursors for plant alkyd resins. However no detailed studies have been conducted on the fatty acid constituents of the oils as a basis for evaluating their nutritional potentials and suitability as base materials for paint alkyd resins.

iii. Production of carotene concentrate from crude palm oil

The hybrid *Tenera* (T) is the major commercial oil palm progeny cultivated in plantation in Nigeria. Crude red palm oil extracted from the mesocarp of *Tenera* consists of saturated and unsaturated fatty acids and also minor components (about 1%) components namely carotnoids, tocopherol and tocotrienols, sterols, ubiquinones, triterpenes, phospholipids, glycolipids, terpenic and aliphatic hydrocarbons.

Palm oil is the richest natural source of carotenes, which possess high vitamin A activity. These micronutrients are vital to human health especially as free radical scavengers, anti-cancer agent, anti-sterile agents and vitamin A precursors.

The percentage abundance of these minor components in crude oil is about 1% but their combined economic value is much more significant. The project therefore, seeks to set out a method for the efficient extraction, purification and characterization of carotene concentrate for encapsulation as dietary supplement via a multi-stage low temperature fractionation procedure.

The project besides improving the human health condition, will also lead to establishment of small-scale industries and diversification of uses of palm oil.

8. Development of the non-metalic mineral sector

Since 1991, the Council has been promoting value addition to industrial raw materials. To date it can be safely said that over 33 industries have been established in various areas of mineral processing.

(i) Phosphate: The phosphate plant was set up to beneficiate raw phosphate available in the country as feedstock to the fertilizer industries in the country. In 2004, the country imported ten million US dollars ($10.0 million) (CBN 2004 Report) worth of phosphate. The high demand of milled phosphate by fertilizer blending companies supported the need for the Council to embark on beneficiation plants.

The pioneering efforts of RMRDC on phosphate led to the establishment of at least 5 phosphate processing plants, namely: Kamiyya Phosphate Mill Ltd, Chiso Phosphate Mill Ltd, Bayaks Phosphate Mill Ltd, Mainaco Phosphate Mill Ltd, Sokoto Phosphate Mills Ltd.

The total supply of phosphate from these plants is currently meeting 40% of the requirement of the Federal Super Phosphate Plant Ltd, Kaduna. Over 1,000 Nigerians are gainfully employed along the value chain. In addition, local engineering capability in the design, fabrication and installation of phosphate processing plants were promoted by the Council.

(ii) Kaolin: Two plants, located in Gwarzo and Kankara are processing raw kaolin into technical grades kaolin, which are supplied to fertilizer and plastics industries. In addition, calcined kaolin has been developed as a substituted imported titanium dioxide in the paint industries. Up to 5% replacement of titanium dioxide has been achieved. Considering that the country imports an estimated 5,000 metric tones of titanium dioxide annually, this project would therefore create a saving of over N200 million per annum.

(iii) Baryte: The Council, in collaboration with private investors, established integrated solid mineral processing plants in Calabar and Owerri tom process non-metallic resources especially barite. Other minerals are diatomite, bentonite, kaolin, limestone, etc. These plants currently supply barite to the oil industry.

The Council also sustained interactions with the Nigerian Content Committee of NNPC and Chevron with a view to generating the synergy on sourcing and processing of some vital minerals in the petroleum sector, notably barite and bentonite which has hitherto been imported. This effort is expected to save Nigeria colossal amount of foreign exchange.

(iv) Talc: The Council promotes processing of talc in order to reduce importation of talc and therefore save foreign exchange for the country. A case in point is the Kagara Talc Processing Project in Niger State. The plant processes talc for industrial use. Other similar plants e.g. Crystal Talc Nigeria Limited, have been established in Niger State following this initiative. To enhance production and increase market, a pulverizer is to be incorporated.

In addition, the Council sponsored research into the production of pharmaceutical grade talc from local deposit. The product has been accepted by some pharmaceutical companies such as Neimeth Pharmaceutical Company Limited and Evans Pharmaceuticals Plc both in Lagos. It is expected that the products would substitute imported talc in the foreseeable future.

Impact of innovative science and technology for raw materials development and utilization in Nigeria

The complete list and details of all on-going R and D projects are in the Annexture. The impact of these implant R and D activities on the mandates of RMRDC as well as the nation are as follows:

- promotion of the commercialization of research results and indigenous inventions,
- promotion of the development of process technologies for new products and ensuring product acceptability,
- promotion of market-driven and consumer led R and D,
- promotion and utilization of local raw materials, and locally developed technologies,
- promotion of value addition to local raw materials,
- promotion of networking between researchers and users of R and D results and investors,
- promoting the establishment of model factories which demonstrate the viability of investments in the processing of local raw materials for investors uptake, who usually are not willing to take risks in the commercialization of R and D results,
- serving as a coordinating body for R and D in the country providing linkages between research and the productive sector. Such research-industry alliances can add value to indigenous raw materials and products and increase the competitive edge of private sector companies,
- encouraging the exploitation of new raw materials for industry's utilization,
- promoting local engineering capability in the design and fabrication of machinery and equipment.

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