current research

- **Production, optimisation and improvement of yield of ethanol and citric acid from fermentation the fermentation of molasses, *Zea mays*, and *Cyperus esculentus***

In the search for new, cheap and sustainable raw materials for the production of ethanol and citric acid, which is important for food and pharmaceutical industries, my research investigated the use of local materials like sugar cane molasses (by-product of the sugar industry) and *Cyperus esculentus* (tuber of a weed) in the production of these products via fermentation using *Saccharomyces cerevisiae* and *Aspergullus niger*. The work involves the production, improvement of yield and optimization of the fermentation control variables. For the first time metal complexing agents was used as metal buffers in the improvement of yield instead of the use of ion exchange resins, which is laborious and expensive. [See Articles no. **1, 2, 3, 4, 5; 7; 9, 10**]. The results obtained have significant application for food, pharmaceutical and Allied industries of Africa. This has been adopted by many industries in Nigeria.

- **Thermo-catalytic conversion of wastes and biomass into useful industrial feed stocks:**

My other ground-breaking research was the thermocatalytic conversion of wastes and biomass, involving the low temperature conversion using a converter which was developed by Bayer and Kutubuddin for the conversion of oil shales into shales using inorganic catalyst. The application was extended to biomass during my visit to the University of Tuebingen as an Alexander von Humboldt research fellow in 1997. Wastes and biomass are converted to oils, which is rich in technical fatty acid that could serve as precursors for the synthesis of oleochemicals like fatty alcohols and fatty amides. Secondary conversion was also carried out to produce diesel oils. The solid material was similarly activated by partial gasification to produce active carbons. I have generated samples of all these findings and have significant contribution to the industries engaging in biomass production, in terms of local sourcing of raw materials. While much of this are yet to be adopted in Nigerian industries, due to lack of support from the government to consume researches from Universities, I have produced doctoral student in this area. Article no. **17, 72, 76, 82 and 100** are the research communication in this aspect.

- **Composition and possible industrial utilisation of seeds, seed oils and other industrial raw materials:**

During the course of my research, I discovered that lack of information on the composition of tropical fruits, seeds, tubers and some other industrial raw materials are responsible for their under-utilization. I then carried out a systematic study on the compositional analysis of the materials in order to unveil their potentials. My article publications such as articles **6, 8, 11, 13, 14, 15, 16, 18, 20, 24, 25, 26, 27, 28, 29, 30, 32, 34, 37, 38, 44, 45, 47, 56, 60, 66, 99** as indicated

are the demonstrations of my outstanding findings in this area. The practical relevance is that if the results are cultivated both at household and industrial sectors, much of the wasted fruits, seeds and tubers in Africa will yield substantial incomes and thus, provide jobs and reduce poverty.

- **Rheological and baking properties of non-wheat flours:**

Over the past 50 years, millions of people in developing countries particularly in Africa have abandoned various fermented staple foods prepared from traditional crops like sorghum, millet, maize, cassava and cocoyam. The reason is that bread and other confectionary products from wheat are tasty and can be eaten with many supplementary foods. Unfortunately, wheat does not grow well in the humid tropics of Africa. A large amount of African meager foreign exchange earnings are expended on the importation of wheat. I was struck by the dearth of research on fermentation of African staple foods to make them have taste and embraced like wheat. The quest for my research is this direction was to explore the possibility of using non-wheat flours in the baking of bread, long before cassava is popularized in Nigeria in 2010. My research focus on the use of polymer gum (*Cissus poplnea)*, local soup thickener to produce bread with over 80% substitutions from cocoyam. The flour has excellent rheology and physical properties of the bread like the loaf volume, loaf weight, crust structure, and the staling rate as well as the organoleptic properties of the bread were unaffected. A real sample of cocoyam bread was produced in my collaborative experiment with another colleague in the Department of Food Technology, University of Ibadan, Nigeria. I have since engaged in advocacy to take the experiment to an industrial level. If this is embraced, it will reduce the loss of foreign exchange earnings, due to importation of wheat flour, and increase the production of bread and other bread-like products through sustainable raw material, and in the long time provide job opportunities through self-reliant on bakery. My publications labeled **12 and 23** below communicate my knowledge products in this direction.

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- **Physicochemical, functional properties and retrogradation behaviour of native and modified starches and protein concentrates of underutilised legumes and cereals:**

Due to shortage of animal proteins and the fact that animals have been implicated in coronary and heart diseases, one of my striking research endeavours involves the development of methods for the isolation, and determination of the functional properties of protein concentrates and isolates. The structures of these proteins are also modified chemically in order to make them functional for specific industrial application that demands good gelation concentration, better oil absorption capacity, better foaming capacity and stability, better emulsifying properties to mention a few.. In the same vein, I have researched extensively on starch, which is a major component of the underutilized seeds, legumes and cereals. This aspect of my study involves both physical and chemical modification of the native starches. The chemical modification

includes oxidation, acetylation, hydroxypropylation, benzylation, carboxymethylation, succinylation and acid thinning. Physical modification involves annealing and heat moisture conditioning. All these techniques are to produce starch derivatives which have applications in food and pharmaceutical industries. Some of our starch derivatives have been as excipients in paracetamol tablets embraced in many pharmaceutical industries in Nigeria. To date, I have produced five doctoral students on this area of research. My following publications are the media outlets of my research success in this area: Articles **19, 21, 22, 28, 31, 33, 35, 36, 39, 40, 42, 46, 48, 50, 51, 52, 53, 54, 55, 57, 58, 61, 62, 65, 67, 68, 71, 81, 92, 93, 94, 97, 105.**

- **Synthesis, kinetics of production and characterisation of oil-modified alkyd resin:**

In my alkyd resin research, I modified conventional alkyd resin with lipids in order to improve both physical and chemical properties. Alkyd resin is a major raw material for the production of paints and other industrial coating materials. My research synthesized short, medium and long chain modified alkyds and I carried out systematic studies of their rate of reaction. Characterization was carried out using FT-IR, ^{1}N-NMR and ^{13}C NMR. Furthermore, I produced acrylated oil modified alkyds which has improved film forming properties, and weatherability of paints. See Article **43** on this,. In addition, chlorinated *Albizia benth* oil modified alkyd resin was synthesized, characterized and reported for the first time through my research enterprise as a don in the University of Ibadan, Nigeria. I produced alkyd resin with improved drying properties, better chemical film forming properties, better scratch hardness, and water and acid resistances [**Article 41]**

- Furthermore, I modified kaolin with sodium salt of rubber and tea seed oils (RSO-Na) to produce nanocomposites rubber vulcanisates as demonstrated in Articles **84, 91, 96 and 98** in the attached publication

- **Kinetic and thermodynamic studies of the adsorption of metals on kaolinite clay**

The strong need for portable water in Nigeria and in sub-Sahara Africa as one of the millennium development goals (MDGs) inspired my research group to search for low cost adsorbents for micropullutant removal in aqueous solutions. My research modified locally obtained kaolinite clay from Ubulu-Ukwu, Delta State, Nigeria, using simple techniques in order to improve the efficiency of the removal of the micropollutants from water and waste waters. My interest in kaolinite is its abundance. The mineral is found in 20 states in Nigeria. I successfully prepared four efficient adsorbents from the kaolinite clay using simple surface functionalization technique. These functionalized clay adsorbents have shown improved rate of micropollutant uptake and enhanced capacity even in the presence of competing ions with excellent selectivity for micropullutants especially the polymer-clay composite adsorbent (Polyvinyl alcohol modified kaolinite clay). The polymer-clay composites modified adsorbent was found to be water stable

and able to remove 60ppm Pb^{2+} and Cd^{2+} to no detectable limits in Inductively Coupled Plasma Atomic emission Spectrometer. The easy recovery of the polymer-clay composites adsorbent makes it attractive for use in fixed bed adsorption systems as against the colloidal clay particles that blocks pores of filters. Optimizing the data from fixed bed studies for a large scale waste water treatment plant revealed that 4kg polymer-clay composite adsorbent (2kg stage) can remove 95% 300 ppm Cd^{2+} in 2.5m^3 aqueous solution in approximately 30 min. in a two stage batch absorber system. The adsorbent in this study was regenerated within 3min – 5min. The idea is being popularized among water industries in south-western Nigeria. My publications from these studies are shown in articles **49, 59, 63, 64, 69, 73, 74, 78, 79, 80, 85, 86, 90, 104, 108**). Two (2) of these publications have each been judged to be among the top twenty five (25) best articles in two different Elsevier journals (see link http://top25.sciencedirect.com/subject/earth-and-planetary-sciences/9/journalapplied-clay-science/01691317/archive/5)

http://top25.sciencedirect.com/subject/chemical-engineering/5/journal/hydrometallurgy/0304386X/archive/18

For two consecutive years (2011 and 2012), two of my publications were rated by Thomson Reuters ISI Science web of knowledge (Essential Science indicators) as the first two top papers in Engineering in Nigeria. This was among six other top articles selected.

- **Fuzzy Logic Modelling of Environmental Compartments**

With the graduation of many PhD students through my research interests, I constituted a research group, using my laboratory, funded through many international research grants, fellowships and awards. Recently, through my leadership, the research group used a novel modelling concept, Fuzzy Logic, to elicit the understanding of the Chemistry of environmental compartments. The concept advocates that an object can belong to two classes at the same time with a membership function between 0 and 1. The membership functions of various evaluated objects are then formulated into evaluation matrix, which can be subjected to various algorithms to formulate the resultant class to which the object belongs. We have applied fuzzy logic to recognize the dispersion pattern of metals in water and sediments; to model the understanding of the fate and speciation pattern of Ni and V in sediments from crude oil exploration area; to model the bio-accumulation trend of metals in aquatic biota; in assessing the usage supports of coastal water for various applications; to evaluate the impacts of industrial activities on the host community of an industrial estate; and to investigate the persistence and bio-accumulation of Cu based fungicide on cocoa among others. Journal publications: **70, 76, 77, 83, 87, 88, 89, 95, 101, 102, 103, 105 and 106** are parts of my research communication to the global academic community on this scientific landmark. . We are currently applying the concept to study and understand other environmental concepts such as organic pollutants.