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**LADOKE AKINTOLA
UNIVERSITY OF TECHNOLOGY,
OGBOMOSO, NIGERIA**

16th

**INAUGURAL
LECTURE SERIES 16, 2016**

**TITLE:
FROM INFANCY TO
ADULTHOOD:
A NEXUS FOR HEALTHY,
SAFE, NUTRITIOUS
AND WHOLESOME FOOD**

By

**Michael Olufisayo
Ologunde**
FNIFST
Professor of Food Chemistry

PLATE 2A:
ASCENSION LINES

PLATE 2B:
TYPES

AMARANTH

GRAIN



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The Vice-Chancellor,
Deputy Vice Chancellor,
Members of the Governing Council here present,
Principal Officers of the University,
Distinguished Members of the University Senate
Academic Colleagues,
Members of the Non-Teaching Staff,
My Lords Spiritual and Temporal,
Friends of the University,
Our Dear Invitees,
Family Members,
Gentlemen of the Press,
Great Ladokites
Ladies and Gentlemen

Preamble

It gives me great pleasure and delight to be given this privilege and opportunity by the Vice Chancellor to deliver this inaugural lecture on the auspicious occasion of my twenty six years of joining the university. I return all glory and adoration to the almighty God for making this day a reality. I consider it a privilege to share my works and experiences with the academic community that has nurtured me these twenty six years. I thank the omnipotent God for making this first inaugural lecture from the Department of Food Science and Engineering, the second from the Faculty of Engineering and Technology, and the sixteenth in the University possible. On this day as always, I return all praises and exaltations to the all sufficient Almighty God who inspite of all the vicissitudes that characterized this journey has made this day a reality. As it is written in the Book of Psalms, 127:1a “**Except the Lord builds the House, they labour in vain that build it.**” I stand here before you today as a living testimony of the house that the Lord builds, and an individual HE has shown mercy and favour to. Praise His holy name.

Emergence of the First Department of Food Science and Engineering in Africa

Since this is the first inaugural lecture from the Department it is appropriate to put history of the emergence of the Department in perspective for the sake of those coming behind us. The history of the creation of the Department of Food Science and Engineering can be traced to the work of Technical Committee who was given the assignment of producing a comprehensive Technical Report for the establishment of a University for the old Oyo State in response to the yearnings of the people of the state. The sub-committee on the Department of Food Technology after reviewing available information observed that the Department as proposed then would only produce technologists and not engineers. Since the proposed new university was to be engineering focused, there was the need to develop a new curriculum that will be engineering based. For example, the establishment of the unit processing operations of turning coffee beans (as harvested on the farm) into coffee beverage without losing any of the organoleptic properties of aroma, colour, taste, etc. of the raw materials is Food Engineering. The plant unit operation for this production is Food Technology. This concept was adopted by the Technical Committee; hence a new Department was born. This new department had initial problems of accreditation with the National Universities Commission (NUC) because of lack of an academic template for its assessment. The Council for the Regulation of Engineering in Nigeria (COREN) could also not accredit the new programme for the same reason. This problem was solved consequent on the composition of a tripartite committee(sponsored by LAUTECH in 2002) and made up of LAUTECH (host and convener), OAU, Ile-Ife (member) and representative of NUC. This committee was chaired by Prof. P. O. Ngoddy, the first and foremost food engineer in the country. This Committee later ratified both the

resource and curriculum of the new programme following which it was adopted as a template by the NUC. It is important to add that following this successful exercise, many departments of Food Engineering sprung up in many universities in Nigeria.

Prof. I. A. Adeyemi was appointed the first head of the new Department in July 1990. He resumed fully in 1991. I joined him some months later. The Department moved to the present office which used to be part of 'Labour line' (as it was then called) in 1992. With the donation of Owodunni Food Processing Laboratory by the patriarch of Owodunni family, late Alhaji Adeleke Owodunni, the Department was on the road to fulfilling its dream of being the first Department of Food Science and Engineering in Africa. The Department which started with a staff of two now has twenty seven academic staff, nineteen laboratory staff including technologists and five administrative staff. Indeed, it has come of age.

Current trends in the food processing industry indeed called for the establishment of a Department of Food Science and Engineering, a clear departure from the usual Food Science and Technology. The aims and objectives of this new department as contained in the University Handbook include:

1. train manpower who will be in the position to produce/manufacture high quality and nutritionally rich food products;
2. train personnel required to establish, manage and direct cottage food industries using locally available raw materials;
3. produce graduates who will be involved in food product development, research and development, processing and preservation;
4. train engineers who will serve the food industry at all levels in food design, food plant and equipment design, equipment fabrication, maintenance and evaluation of food processing equipment and plants; and
5. train manpower who can work in higher educational and research institutions, government establishments/parastatals and intergovernmental organizations.

In addition to a wide array of equipment for teaching and research made available by the University and which made it possible to fulfill its mandate of turning out more than 1000 graduates into the labour market over the past fifteen years, the Department now boasts of a wide array of up to date analytical equipment to assist students and staff in their works.

Mr. Vice-Chancellor sir, my colleagues and I engaged in cutting edge research most of which not only seek to promote the fundamental objectives of setting up the Department and University but also to meet the requirements of national economic development. In this connection, the contributions of the Department to the delivery of healthy, safe, nutritious and wholesome food on the dining table of Nigerians will be highlighted in the course of this lecture. I am proud to confirm to this august gathering that all the aspirations of the founding fathers of this university as espoused in the Technical Committee Report setting up this University have been met and surpassed.

IN THE BEGINNING.....

My first attempt at doing research was with my undergraduate project, the title of which was: ***Glucose-6- phosphatase activity in liver of rats fed on prolonged high cassavadiet.*** This was my initiation into investigative analysis. Professor E. A. Anosike (now Emeritus Professor at the University of Port Harcourt) was my supervisor. He did a lot to sharpen my investigative skills and actually prepared the foundation on which I stand here today. As it later turned out to be, this work provided the fulcrum on which subsequent works stood. The study which sought to assess the residual concentration of cyanide in processed cassava meals (Gari, fufu) had as its main focus the qualitative and quantitative estimation of a chemical contaminant, cyanide. I never knew that I was charting a course. The study that came immediately thereafter: ***Development of Conophor nut-based***

cereal snack foods-Biscuit also had something to do with determination of the concentration of toxicant present in the study material. This work (M.Sc.) was supervised by late Mr. M. B. Adebona. Ever since, my research activities had danced around contaminants whether in plants, animals, water and lately assessment of environmental contaminants in food and feed, all with a view to producing, healthy, safe, nutritious and wholesome food products.

My journey in the academic sector which took me to two continents of the world, working in some of the world's best laboratories and in collaboration with accomplished and outstanding scientists has produced several peer-reviewed publications. These works can be summarized under the following headings:

1. Nutrient assessment of foods:

- ✓ Nutrition in the most vulnerable group (children and women)
- ✓ Anti-nutritional factors
- ✓ Determination of Toxic constituents of Foods
- ✓ Grain Amaranth Research Project
- ✓ Digestibility studies

2. Nutrient bioavailability:

- ✓ Estimation of macro and micro nutrient contents of foods
- ✓ Determination of Iron Bioavailability in grain amaranth

3. Food fortification:

- ✓ Use of Soy Bean flour as a food vehicle of iodine fortification
- ✓ Fortification of Spaghetti with vegetable protein sources

4. Environmental health and food safety concerns:

- ✓ Contamination of Street foods
- ✓ Contamination of food and water sources consequent on Crude Oil Processing.
- ✓ Contamination of underground water aquifer in cassava processing sites.
- ✓ Assessment of quality of urban water sources for possible contamination.

It can be concluded from the above that the focus of my research has been the **provision of healthy, safe, nutritious and wholesome food products for the nutritional wellbeing of man from the time of conception through infancy to adulthood**. This concern was borne out of the belief that good food not only opens the door to wealth but that it also opens the door to longevity. Whatever we are later in life is determined by activities arising from good food nutrients available to us during development from the foetus. The health of the mother is an important determinant of the health of the offspring from infancy to adulthood. It is in this context that the first food we consume as neonates must be highly nutritious. Any departure from this will invoke malnutrition which may bear serious repercussions for the future of the individual. Also it is during this period that the growing child has the greatest challenge of meeting iron and zinc requirements, both minerals being critical for the development of the neonate. Good food that contains balanced nutrition is a crucial window for the promotion of optimal growth, health, intellectual performance, work capacity, reproductive outcomes and overall healthy adulthood. There is abundant epidemiological evidence to support the fact that there is association between fetal malnutrition, morbidity and mortality in adult life.

For an expository presentation of the topic: ***FROM INFANCY TO ADULTHOOD; A nexus for healthy, safe, nutritious and wholesome food***, it is important to have a thorough understanding of

what constitutes a nutritious food, what the absence or lack of it causes and strategies of ameliorating it. Let me provide some background information on this context.

BACKGROUND INFORMATION

Malnutrition has severe consequences on human wellbeing either in terms of aggravating poverty, irreversible mental damages, stunted growth among children, deafness, decrease in future earnings of individuals and drop in the country's gross national domestic product due to short life span, inactivity and unhealthiness. Malnutrition is a complex, multi-dimensional concept not amenable to measurement using a single indicator (Barrett, 2010). Consequently it is appropriate to undertake a review of the best current estimates on prevalence and trends in key indicators of the three basic forms of malnutrition. **Undernourishment** is the outcome of insufficient macronutrient (calorie and protein) intake. It is estimated by Food and Agriculture Organization (FAO) as the prevalence and number of people whose dietary energy supply or food intake is insufficient to meet their requirements. Undernourishment contributes to negative health outcomes measured by anthropometric indicators such as **underweight** (low weight-for-age), **wasting** (low weight-for-height), or **stunting** (low height-for-age), especially among children. Stunting captures the life-long negative effects of food intake deficiency and disease (Victoria *et al.* 2008), afflicted 165 million children globally in 2011 (UNICEF, WHO and The World Bank, 2012) and one of every three Nigerian children below the age of five years (ICF/Macro 2014). Wasting captures shorter-term, acute episodes of malnutrition. Underweight is a product of the other two indicators.

The most recent National Demographic and Health Survey indicated that among under-five children in Nigeria, two of every five, one out of every five and one of every eight are shorter for their age, do not weigh enough for their ages and have inadequately developed muscles respectively following malnutrition (ICF/Macro, 2014). In Nigeria, more than 10 million under-five children are stunted and one-third of preschool-age children have vitamin A deficiency, which has a direct impact on a child's immune system and sight. Anaemia in preschool-age children is at 76 percent. **A recent report from United Nations Children Fund (UNICEF) indicated that "Over 1.6 million Nigerian children are suffering from acute malnutrition, this means that the children are nine times likely to die than normal children and if nothing is done about it, we will likely lose 300,000 of these children."**This is one of the major reasons why the school feeding programme is highly relevant, important and must be given all the attention it deserves.

Micronutrient malnutrition refers to deficiencies in vitamins and minerals critical to good health and is the outcome of a combination of poor dietary composition and disease. There are many essential micronutrients but only Vitamin A, iron, and iodine deficiencies are routinely monitored on a large-scale and in a cross-nationally comparable fashion. Vitamin A deficiency (VAD) impairs proper growth and increases vulnerability to infections. VAD affected over 163 million under five children in 2007, a prevalence of about 31 percent (UNSCN, 2010).

Malnutrition has a debilitating effect throughout the life-cycle. Maternal malnutrition during pregnancy is a primary cause of Intra Uterine Growth Retardation (IUGR) world-wide. Malnourishment of today would show its ugly head in terms of low Intelligence Quotient (IQ) in children/adults in about twenty years' time. Percent transition from secondary to tertiary levels of education among other indices would by that time drop significantly. Elimination of micronutrient deficiencies has been estimated to have the capacity to raise the world's IQ by 10 points with an attendant positive shift in education and working capacity. It is in this context that one wants to commend the Government of the State of Osun and indeed all state governments that have embraced the School feeding programme. One is equally happy that the Federal Government of Nigeria has decided to take over the entire cost of funding estimated at about N95.0 billion annually as part of its welfare programme. The programme's objective is to reduce malnutrition as much as possible

among the vulnerable group, the primary school age group, improve cognitive performance and provide a better tomorrow for our children. You will all agree with me that no legacy (leaving something in the people) can be greater than this. The various governments are laying good foundation for children to be imbued with improved IQ in the future.

However, as successful as it is presently, school feeding (with due apology) goes beyond providing food macromolecules (rice, eggs, fish, yam porridge, etc.) only. Food micronutrients (that will incorporate all critical micronutrients (vitamin A, iron, iodine, zinc among others) needed in the first 1000 days of life) must be provided in a complementary fashion. This requirement calls into play the need for substantial input by Food Scientists, Food Engineers, Nutritionists and other interested stakeholders. This team will work collaboratively to develop and package new food products with extended shelf life using locally available and abundant agricultural raw materials. This products will alleviate short-term hunger, improve macronutrient and micronutrient intake, enhance nutrition and child health, increased learning and decreased morbidity. With an estimated daily consumption by more than 40 million school children nationwide, this is an outfit with potential success story.

Malnutrition results from inadequate dietary intake following poor availability of food, poor access to food, poor quality of food, loss of nutrients during processing and/or preparation; poor utilization occasioned by poor care practices, presence of nutrient inhibitors, action of contaminants and pollutants limiting nutrient availability, among other factors. Contaminants have long been known to influence nutrient bioavailability and thereby contributing to the scourge of malnutrition in developing countries like Nigeria. A bidirectional relationship has also been established in which pollutants increase the risk of malnutrition and malnutrition enhances the toxicity of pollutants.

As a Food scientist/researcher, I have focused on breaking the cycle of malnutrition to foster good health, improved wellbeing and development in all age groups especially the nutritionally vulnerable population, children and women. I have done all these by conducting Laboratory exercises/analysis, research, surveys, intervention studies, nutrition education on best practices etc. to reduce the anti-nutritional factors in foods, promote dietary diversification, improve utilization of diverse food sources, promoting increased diet quality through fortification of commonly consumed foods, development of new food products, increased utilization of nutrient rich food sources, and exploring the consequences of environmental pollution and contamination on food sources and effect on bodily organs.

With this understanding in the background, I undertook my first major assignment which was re-sharpening of my analytical tools. In 1986, Prof. O. L. Oke's Research Group was awarded one hundred thousand United States Dollar (USD 100,000.00) Grant by the USAID to study Africa's Food Problems with emphasis on the utilization of GRAIN AMARANTH. In addition, the fund was also to assist in establishing an Academic Research Linkage programme between the Department of Chemistry at Obafemi Awolowo University, Ile-Ife and its counterpart at Howard University, Washington DC, USA. Under this arrangement, and as a direct beneficiary, I found myself at the Department of Chemistry, Howard University, Washington DC. Being a Biochemistry graduate, with exposure only in biochemical analysis, I had to register for and undertake lectures in postgraduate courses in Advanced Chemical Analysis and Instrumentation for three semesters. Furthermore, Howard University does not have a Department of Food Science and Technology and since part of my research protocols included food product development, dietary assessment and contribution of food items, macro and micro food nutrient analysis, I went over to the Department of Human Nutrition and Dietetics to register for and undertake lectures in postgraduate courses in Advanced Human Nutrition and Demographic Surveys for two semesters. This exercise I found to be very helpful as it complemented my Food Science and Technology major. Permit me, Mr. Vice Chancellor to mention at this juncture that Prof. O. L. Oke, an outstanding and distinguished

academic of international repute and an iconic first Vice Chancellor of this great institution assisted by Prof. Oladapo A Afolabi, pioneer Professor and Head, Department of Pure and Applied Chemistry of LAUTECH and by the special grace of God, the first Nigerian University Professor to occupy the distinguished office of the Head of Service of the Federal Republic of Nigeria, supervised this grant and research on behalf of USAID. Dr. Robert. L. Shepard, a chemist and Director at the American Nuclear Regulatory Commission (on sabbatical at Howard University) and late Prof. J. B. Morris, both of the Department of Chemistry, Howard University, Washington DC coordinated the American segment. With the assistance of Dr. Allan J Sheppard (late), Chief Chemist at the Centre for Food Safety and Applied Nutrition (CFSAN), I secured a space in his laboratory which enabled me to make use of the advanced analytical facilities available at the Laboratories of United States Agency For Food Drugs Administration and Control, 200C Street, Washington DC to carry out further analysis on my work. The accompanying pictures tell the stories.



Researcher using binocular microscope to study the behavior of fluid during super critical fluid extraction, at US FDA Laboratory

PLATE: 1A



Researcher studying fatty acid printout produced by Gas chromatograph-Mass spectrograph[GC/MS] at the USFDA Laboratory

PLATE: 1B

IMPACTS OF HUNGER AND MALNUTRITION:THE FOOD TECHNOLOGIST'S PERSPECTIVE

Hunger and malnutrition continue to cause enormous world-wide human suffering. The most serious nutritional deficiencies are various forms of protein-energy malnutrition (PEM), particularly affecting young children. The United Nations Children's Fund (2001) published the *First Report on the World Nutrition Situation*, which states that in most parts of the world, nutrition has improved over the last 25 years: this is reflected in a reduction in infant and child mortality rates. Malnutrition (as indicated by infant and child mortality, underweight and low birth weight) has remained stable in South America, decreased in Asia and Central America and increased in sub-Saharan Africa following a long-term decline in food supplies. Climate change is another major concept affecting health and nutrition presently. Climate change directly affects all the four dimensions of food security (availability, accessibility, utilization and stability) and consequently nutrition. It undermines efforts to protect the lives and livelihoods of the over 1 billion food insecure people and increases the risk of hunger and malnutrition. Undernutrition is already the single largest contributor to the global burden of disease, killing 3.5 million people every year, almost all of them, children in developing countries. **This clearly confirms that the solutions to many of the underlying problems of undernutrition in the Third World lie outside the professional scope of nutritionists, as they involve food availability (food processing and storage to make nutrient-rich food available all the year round) and distribution. Consequently, in our field of food science, technology and engineering, we have keyed into solving the problems of malnutrition from diverse approaches.**

We are vigorously pushing for increased utilization of local resources and identification of grossly underutilized crops in addressing malnutrition especially as it concerns infants. While the Food Scientist is primarily concerned about food product development and meeting all the quality criteria of safe, healthy, nutritious and wholesomeness, the nutritionist's interest is about what happens to this food and the effects it is expected to perform once it enters the human body.

Several factors may conspire to cause malnutrition, including infection, but the problem is compounded by the failure to provide infants in the Third World with weaning foods of adequate energy density. Protein energy malnutrition predisposes children to measles, diarrhoea and pneumonia. If energy intake is inadequate, then intake of other nutrients, including protein, is likely to be inadequate. Our work on the USAID-Sponsored Grain Amaranth Project was an attempt to domesticate the entire hypothesis made earlier as well as providing long term nutrition-based solutions for use on the African continent (Oke, 1984; Ologunde *et al*, 1990; Fashakin *et al*, 1986). The grain amaranth (local name: Efofete with dark coloured seeds), an underutilized plant with promising economic prospect as a food source is indeed a good intervention in situations of protein-energy and protein-calorie malnutrition especially in the third world. This project is discussed.

GRAIN AMARANTH PROJECT

Malnutrition is widespread in Nigeria and other developing countries. It is a major direct and indirect cause of infant and childhood mortality and morbidity. Besides children, other vulnerable individuals such as people living with HIV and AIDS (PLWHA) have high nutrient requirements. The poor are unable to access adequate amounts of nutrient-rich foods to meet dietary requirements and this is the major reason for the high prevalence of malnutrition. There is therefore a need to identify nutrient-rich foods that can be produced inexpensively (available, accessible and affordable) to meet the nutrient requirements of these vulnerable groups. Grain amaranth, a little known crop of the Americas, is grown either as a grain crop or as a leafy vegetable. Despite its obscurity, it offers important promise for feeding the world's hungry. In the National Academy of Sciences 1975 study of Under Exploited Tropical plants with Promising Economic Value, amaranth was selected from among 36 of the world's most promising crops. It has the potential to contribute to addressing the nutritional needs of vulnerable people because of its high protein content, superior protein quality, high content of essential fatty acids and micronutrients.

Amaranths, which comprise the genus *Amaranthus*, are widely distributed, short-lived herbs, occurring in temperate and tropical regions. They are mostly hardy, weedy, herbaceous and fast-growing cereal-like plants that produce high protein (ca 17%) grains in large terminal or axial sorghum-like inflorescences (Opute, 1979), (see Plate 2A). They may well become the primary staple cereal crop upon which millions of people in developing countries will depend in the near future. Grain amaranth is known to perform well in tropical and sub-tropical climates, although strains native to the humid tropics such as in West-Africa sometimes produce poor yields and contain anti-nutritive factors (Afolabi and Oke, 1981). In recent years, however, new improved lines of high-yield grain amaranth have been developed at Rodale Research Center, Kutztown, Pennsylvania, USA. These are strong and amenable to mechanized farming practices. As part of our efforts aimed at domesticating the crop at Ile Ife, Nigeria, before its use in food product development, nineteen ascension lines of grain amaranths were grown and found to produce encouraging yields (2976 kg/ha), comparable with those of other grains such as maize (3180 kg/ha) and wheat (2275 kg/ha). These varieties were used for all the analysis carried out. *A. palmeri*, *A. hybridus*, *A. hypochondriacus*, *A. cruentus* and *A. caudatus* are the main grain species (Teutonico and Knorr, 1985). Amaranth produces a large amount of biomass in a short period of time (Kauffman and Weber, 1990) and therefore has the potential to contribute to a substantial increase in

world food production. Grain yield of up to 5,000 kg/ha has been reported (Stallknecht and Schulz-Schaeffer, 1993).



PLATE 2A: AMARANTH ASCENSION LINES



PLATE 2B: AMARANTH GRAIN TYPES



PLATE 2C: AMARANTH GRAIN UTILIZATION



PLATE 2D: AMARANTH INDUSTRIAL PRODUCTS

The effectiveness of using grain amaranth flour in food recipes suitable for the palate has been well demonstrated by different authors including the today's lecturer. Grain amaranth was used as seeds or flour to make products such as cookies, cakes, pancakes, infant weaning foods, bread muffins, crackers, pasta, semolina and other products.

NUTRITION AND HEALTH BENEFITS OF GRAIN AMARANTH CONSUMPTION

Consumption of grain amaranth is reported to have nutritional and health benefits, ranging from a general improvement in well-being to prevention and improvement of specific ailments and symptoms including recovery of severely malnourished children and an increase in the body mass index of people formerly wasted by HIV/AIDS (SRLP, 2005; Tagwira *et al.* 2006). Tagwira *et al.* (2006) documented perceived benefits of consuming grain amaranth among communities in Zimbabwe. The communities claimed that eating grain amaranth made them feel healthier and they noticed improvements in the health of their children. Specific health improvements noted included improvement in appetite, fast healing of mouth sores and herpes zoster, and weight gain for People Living with HIV and AIDS (PLWHAs).

Table 1: Amino acid profile of grain amaranth

Material	No	Thr	Lys	Ileu	Leu	Phe	Tyr	Met	Val	Asp	Ser	Glu	Gly	Ala	His	Arg	Cys
<i>A. hypochondriacus</i>	718	2.9	4.2	3.6	3.3	2.9	3.3	1.7	3.4	6.0	4.0	14.1	5.2	2.8	1.4	6.4	3.9
<i>Unknown</i>	662	3.3	5.7	3.6	4.6	2.8	4.1	2.2	4.3	8.0	5.0	18.6	7.1	3.3	1.6	8.7	2.2
<i>A. cruentus</i>	1034	2.5	5.3	3.9	4.4	3.3	3.7	1.9	4.1	6.3	4.7	15.8	6.7	3.1	1.1	8.1	2.0
<i>A. cruentus</i>	434	4.7	5.0	4.0	3.4	2.8	4.8	1.6	4.0	7.5	5.4	18.4	6.5	3.1	1.5	7.5	1.8
<i>A. cruentus</i>	1011	2.5	4.0	3.6	3.8	2.9	3.6	1.7	3.7	6.0	4.1	13.2	5.0	2.7	1.3	6.7	2.2
<i>A. hypochondriacus</i>	1046	3.2	4.5	2.2	5.4	3.1	4.5	1.9	4.4	8.0	4.4	17.1	6.9	3.1	1.6	7.8	2.9
<i>A. hypochondriacus</i>	1024	1.9	4.5	3.7	3.0	3.0	3.3	1.7	3.2	5.2	3.6	12.5	4.9	2.7	1.3	8.2	1.5
<i>A. caudatus</i>	988	4.1	5.9	3.9	5.8	3.2	3.3	2.2	4.7	7.8	5.1	19.3	7.8	2.6	1.9	7.8	2.2
<i>A. caudatus</i>	713	3.5	5.4	3.7	5.1	3.1	4.4	2.1	4.6	8.0	6.8	18.8	6.7	3.1	1.7	8.9	3.1
<i>A. hypochondriacus</i>	674	4.6	4.9	3.6	3.4	2.8	4.8	1.7	3.5	7.6	5.2	17.6	6.4	3.1	1.5	7.4	1.4
<i>A. hypochondriacus</i>	646	2.8	4.2	3.9	3.5	3.1	3.4	1.8	3.3	6.0	4.2	14.9	6.0	3.0	1.4	6.4	1.6
<i>Unknown</i>	004	2.5	5.3	3.6	4.3	3.3	3.8	2.2	4.6	6.3	4.1	14.2	5.7	2.8	1.4	6.4	1.5
<i>A. hybridus</i>	1047	3.3	6.0	3.6	4.7	3.0	4.1	2.1	4.4	7.4	4.9	17.6	7.1	3.3	1.6	8.3	2.1
<i>A. cruentus</i>	LOCAL	2.5	4.8	3.0	4.2	2.5	2.8	1.6	3.3	5.4	4.3	11.3	5.4	2.6	1.1	4.0	2.3

Values are expressed as g/16gN and are means of 8 replicates.

SOURCE: Ologunde, M. O., Ayorinde, F. O., Shepard, R. L., Afolabi, A. O. and Oke, O. L. (1992). Chemical Evaluation of Exotic Grain Amaranth Seeds Planted in the Humid Lowlands of West Africa. *Journal of Tropical Agriculture*. 69 (2) 105-110).

Amaranth consumption was also associated with higher milk production among breast feeding mothers (Afolabi and Oke, 1981). The improvements in general well-being and health reported by people who included grain amaranth in their diets are generally explainable by its high nutritional value.

Table 2. Protein quality of raw and cooked cereal and amaranth grain

Grain	Protein Quality	
	Raw	Cooked
Maize	1.49	1.66
High Quality Maize	2.79	2.76
Sorghum	0.88	0.53
Whole Wheat	1.34	1.66
Rice	2.00	1.91

Amaranth sp.	1.73*	3.07*
A. caudatus	2.06*	3.63*

* NPR (Net Protein Ratio): Other values PER
(Protein Efficiency Rating)

SOURCE: Shepard, R. L., Ayorinde, F. O., Afolabi, A. O. **Ologunde, M. O.** and Oke, O. L. (1992). Chemical Evaluation of Exotic Grain Amaranth Seeds Planted in the Humid Lowlands of West Africa: In Proceeding of Amaranth Conference, Kuntztown, Pennsylvania, USA.

Table 3. Effect of processing on the protein quality of amaranth grain

Amaranth Product	Ave.Wt. gain	NPR	Protein Digest, %	Available Lysine, %
Raw	25	2.36	76.4	0.91
Cooked	48	2.80	72.9	0.93
Toasted	14	1.54	59.5	0.58
Casein	51	3.57	92.5	-

SOURCE: Shepard, R. L., Ayorinde, F. O., Afolabi, A. O. **Ologunde, M. O.** and Oke, O. L. (1992). Chemical Evaluation of Exotic Grain Amaranth Seeds Planted in the Humid Lowlands of West Africa: In Proceeding of Amaranth Conference, Kuntztown, Pennsylvania, USA.

Table 4. Protein quality of various cereal grains and amaranth relative to casein

Grain	Relative Protein Quality
Amaranth	83.6
Common Maize	63.7
High Quality Maize	92.3
Sorghum (white)	68.6
Sorghum (red)	71.4
Whole Wheat	70.2
Wheat Flour	49.2
Oats	84.5
Rice	90.2
Casein	100.0

SOURCE: Shepard, R. L., Ayorinde, F. O., Afolabi, A. O. **Ologunde, M. O.** and Oke, O. L. (1992). Chemical Evaluation of Exotic Grain Amaranth Seeds Planted in the Humid Lowlands of West Africa: In Proceeding of Amaranth Conference, Kuntztown, Pennsylvania, USA.

Some specific nutritional and health benefits of amaranth consumption have been elucidated (Bressani *et al.*, 1987). Amaranth oil was shown to contain about 5.0% oil with a high level of unsaturation (combined linoleic and oleic acid occurrence of between 70-80%) and between 2% and 5% of squalene (Ayorinde *et al.*, 1989; Ologunde *et al.*, 1990; and Afolabi *et al.*, 1989). Chemical analysis of the seed oil gave a significant quantity of free fatty acids (7.9%) and triglycerides (Shepard *et al.* 1988). Total poly unsaturated fatty acids [PUFA] were observed to be in the region of 42-53% (Ayorinde *et al.*, 1989). These PUFA belong to the group called essential fatty acids. They are required in human diets. Majority of them cannot be synthesized by mammals but must be obtained from plant sources, in which they are very abundant. Linoleic acid is a necessary precursor in mammals for the biosynthesis of a group of fatty acid derivatives called prostaglandins, hormone-like compounds which in trace amounts have profound effects on a number of physiological activities.

Table 5: Fatty acid composition of grain amaranth

Material	No	C ₃₀ H ₅₀	TUSFA	TSFA	TPUFA	SUFA Index
A. hypochondriacus	718	3.1 (0.1)	74.4	21.7	51.7	0.29
Unknown	662	3.0 (0.0)	75.4	21.3	51.6	0.28
A. cruentus	1034	3.3 (0.1)	77.3	20.4	47.0	0.26
A. cruentus	434	4.3(0.0)	75.8	18.8	42.3	0.25
A. cruentus	1011	3.4 (0.2)	80.8	19.0	51.3	0.24
A. hypochondriacus	1046	2.8 (0.0)	76.3	20.9	50.0	0.27
A. hypochondriacus	1024	5.0 (0.2)	75.3	20.6	46.1	0.27
A. caudatus	988	3.2 (0.3)	74.7	22.4	51.3	0.29
A. caudatus	713	3.8 (0.1)	75	20.4	45.8	0.27

A. hypochondriacus	674	2.9 (0.4)	76.1	21.1	50.5	0.28
A. hypochondriacus	646	3.2 (0.1)	75.6	21.3	52.4	0.28
Unknown	004	1.8 (0.0)	78.2	19.8	54.7	0.25
A. hybridus	1047	4.4 (0.1)	75.1	20.0	52.5	0.26
A. cruentus	LOCA L	2.4 (0.1)	75.5	22.4	52.3	0.29

TUSFA, Total unsaturated fatty acid

TPUFA, Total polyunsaturated fatty acid

Values are expressed as percentage fatty acid

TSFA, Total saturated fatty acids

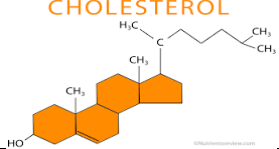
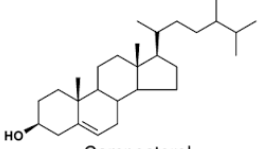
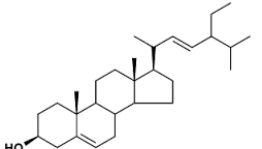
SUFA, Saturated/ unsaturated fatty acid ratio

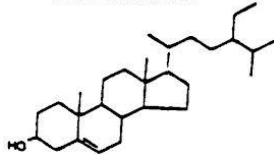
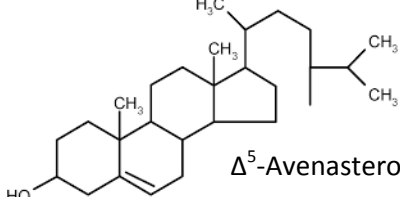
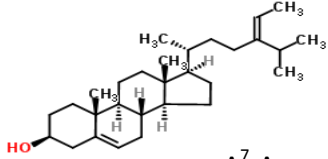
Values are means of 8 replicates with S.E. Min brackets

Source:Ologunde, M. O., Ayorinde, F. O., Shepard, R. L., Afolabi, A. O. and Oke, O. L. (1992). Chemical Evaluation of Exotic Grain Amaranth Seeds Planted in the Humid Lowlands of West Africa. *Journal of Tropical Agriculture*. 69 (2) 105-110).

Amaranth oil was also investigated to determine the profile of the unsaponifiable fraction. This became necessary if the plant seeds can truly serve as a source of protein especially for the elderly. In a series of investigations carried out at the Headquarter Laboratory Complex of United States Food and Drug Administration, 200 C Street, Washington DC, USA, using a combination of state of the art analytical equipment and under the supervision of experts in the use of each equipment: Infra-red Spectroscopy (IR), High Performance Liquid Chromatograph (HPLC) Combined Gas Chromatograph-Mass Spectrometry (GC-MS), Liquid Chromatograph-Mass Spectrometry (LC-MS), Proton-Nuclear Magnetic Resonance (P-NMR), ¹³C-Nuclear Magnetic Resonance (¹³C-NMR), Gaschromatograph/Matrix isolation/Fourier transform/Infra-red (GC/MI/FT-IR) including supercritical fluid extraction, the identity, fragmentation patterns and chemical shifts of the sterols present in the unsaponifiable fraction were revealed for the first time in the literature (Ologunde *et al.*, 1992). The observed chemical shifts are contained in Table 6. The significance of this information which is being reported for the first time in literature has to do with its ability to lower cholesterol levels including the low density lipoproteins (LDL) and triglycerides. Apart from this, they could form the basis of finger printing for the detection of adulteration of amaranth oil.

Table: 6Proton-nuclear magnetic resonance: some diagnostic chemical shifts

Sterol	Chemical shifts
<p style="text-align: center;">CHOLESTEROL</p>  <p style="text-align: center;">CHOLESTEROL</p>	H-21 (3H, d, J=6.1 H ₂) at 0.905ppm, H-26 (3H, d, J=6.2 H ₂) at 0.800ppm, H-27 (3H, d, J=6.0 H ₂) at 0.830ppm, H-6 (1H, br s) at 5.459ppm (used as standard).
 <p style="text-align: center;">Campesterol</p>	H-21 (3H, d, J=6.1 Hz) at 0.910ppm, H-26 (3H, d, J=6.0 Hz) at 0.800ppm, H-27 (3H, d, J=6.0 Hz) at 0.850ppm, H-6 (1H, br s) at 5.359ppm, characterize Δ ⁵ , 24 CH ₃
 <p style="text-align: center;">Stigmasterol</p>	H-29 (3H, t, J=7.1 Hz) at 0.804ppm, H-6 (1H, br s) at 5.35ppm, H-22 (1H, dd, J=7.5 Hz) at 5.015ppm, H-23 (1H, dd, J=7.5 Hz) at 5.159ppm, characterize Δ ⁵ , 22, 24 C ₂ H ₅

<p style="text-align: center;">beta-sitosterol</p> 	<p>H-21 (3H, d, J=6.5 Hz) at 0.921ppm, H-29 (3H, t, J=7.3 Hz) at 0.845ppm, H-6 (1H, br s) at 5.359ppm characterize Δ^5, 24 C₂H₅</p>
 <p style="text-align: center;">Δ^5-Avenasterol</p>	<p>H-25 (1H, m) at 2.819ppm, H-28 (1H, m) at 5.115ppm, H-6 (1H, br s) at 5.359ppm characterize Δ^5, 24 (28), with the configuration of the ethylene bond as the Z-isomer</p>
 <p style="text-align: center;">Δ^7-Avenasterol</p>	<p>H-29 (3H, d, J=6.6Hz) at 1.591ppm, H-25 (1H, m) at 2.830ppm, H-7 (1H, br s) at 5.153ppm, characterize Δ^7, 24 (28), with the configuration of the ethylidene bond as the Z-isomer</p>

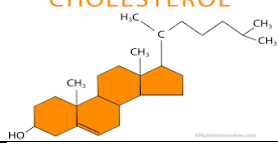
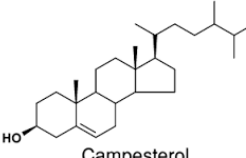
Source: Ologunde, M.O., Ayorinde, F.O., Shepard, R.L., Afolabi, O.A. and Oke, O.L. (1991). Sterols of seed oils of *Vernoniagalamentis*, *Amaranthuscruentus*, *Amaranthuscaudatus*, *Amaranthushybridus* and *Amaranthushypochondriacus* Grown in the Humid Tropics. *J. Sci. Food Agric.*, **58**, 221-225.

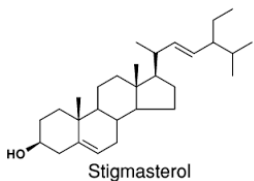
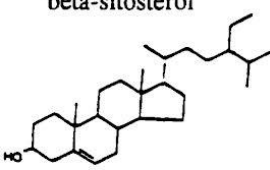
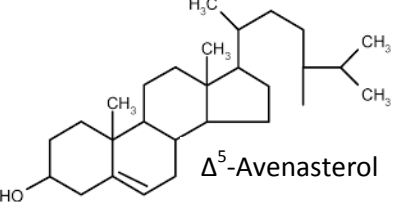
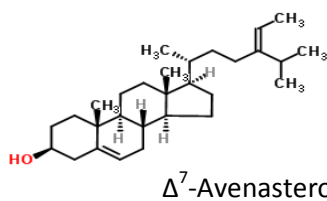
FURTHER IDENTIFICATION OF STEROLS BY MASS SPECTROMETRY

The observed mass spectral diagnostic ions detected are contained in Table 7. The significance of this information which is being reported for the first time in literature for grain amaranth is that they could in addition to information in Table 5 serve as further confirmatory steps for the detection of adulteration in amaranth oil.

Based on the outcome of these findings, there appears to be no compositional reason why amaranth cannot be used as a rich source of protein most especially in infant food formulation as well as food for the geriatric patients. The presence of the sterols in amaranth is a nutritional advantage as they are prominent members of a new class of compounds referred to as nutraceuticals.

Table: 7 Principal fragmentation ions from mass spectral patterns

Peak No	Sterol	Characteristic diagnostic ions.
IA	<p style="text-align: center;">CHOLESTEROL</p> 	<p>M⁺ (386, 100%), M⁺-CH₃ (371, 33%), M⁺-H₂O (368, 43%), M⁺-side chain (273, 28%), M⁺-85 (301, 40%) and M⁺-111 (275, 75%), characterize Δ^5 sterols (used as standard).</p>
I	 <p style="text-align: center;">Campesterol</p>	<p>M⁺ (400, 99%), M⁺-CH₃ (385, 26%), M⁺-H₂O (382, 35%), M⁺-side chain (273, 21%), M⁺-85 (315, 46%) and M⁺-111 (289, 41%), M⁺-145 (255, 20%)</p>

II	 <p>Stigmasterol</p>	M^+ (412, 100%), M^+-CH_3 (297, 7%), $M^+-C_2H_5$ (383, 0%), M^+-H_2O (394, 7%), M^+ -side chain (272, 30%), M^+-157 (255, 55%) and M^+-43 (369, 12%) and ratio of ion intensities of M^+ against M^+ -side chain and m/z 314 (13%) is characteristic of Δ^5 , 22
III	 <p>beta-sitosterol</p>	M^+ (414, 100%), M^+-H_2O (396, 35%), M^+ -side chain (273, 20%), M^+-85 (329, 39%) and M^+-111 (303, 39%), M^+-159 (255, 18%) characterize Δ^5
IV	 <p>Δ^5-Avenasterol</p>	M^+ (412, 100%), M^+-CH_3 (397, 10%), M^+-H_2O (394, 5%), M^+ -side chain-2H (271, 65%), M^+-43 (369, 20%) and M^+-98 (314, 19%) due to allylic cleavage through C22 (23) characterize Δ^5 , 24 (28)
V	 <p>Δ^7-Avenasterol</p>	M^+ (412, 100%), M^+-CH_3 (397, 3%), M^+-H_2O (394, 2%), M^+ -side chain-2H (271, 100%), M^+-42 (369, 0%) and M^+-85 (327, 0%), M^+-98 (314, 30%), M^+-157 (255, 10%)

Source: Ologunde, M.O., Ayorinde, F.O., Shepard, R.L., Afolabi, O.A. and Oke, O.L. (1991). Sterols of seed oils of *Vernoniagalamentis*, *Amaranthuscruentus*, *Amaranthuscaudatus*, *Amaranthushybridus* and *Amaranthushypochochriacus* Grown in the Humid Tropics. *J. Sci. Food Agric.*, **58**, 221-225.

FOOD PROCESSING TO REMOVE TOXIC CONSTITUENTS

ANTI-NUTRITIONAL FACTORS

Another major factor that causes malnutrition is the presence of anti-nutritional factors in foods. These anti-nutritional factors are nutrient inhibitors or toxic substances. Anti-nutritional factors can be classified broadly as those naturally present in foods and those due to contamination. For example, those of fungal origin or may be related to soil and other environmental influences as observed in crude oil processing locations. These factors modify the nutritional value of the individual foods, and some of them have very serious consequences on the health of the consumers (FAO, 1997). Thus some of my research efforts were geared towards reducing the anti-nutritional components of foods to increase nutrient bioavailability. The most important ones are here discussed.

These are tannins, saponins, goitrogens, phytates, oxalates. They reduce nutrient digestibility and in the process make useful food nutrients needed for growth and unavailable to the body. However a number of them are removed or destroyed in the course of processing thereby enhancing the food value of the raw food items. Some of these processing steps include: soaking, cooking, fermentation, germination and by the use of enzymes.

The UN Millenium Project (2005) has indicated the potential for poverty alleviation in Africa through appropriate irrigation technology. However, increase in the use of water for farming conflicts with the need to increase water use for industrial and domestic purposes. Breeding for drought tolerance in crops widely used in Africa as well as promoting traditional drought-tolerant crops are potential ways of mitigating the impacts of climate change in this continent. Ironically,

some of Africa's native drought-tolerant crops are also some of the least researched worldwide and are thus referred to as "orphan crops". One such crop is pigeon pea (*Cajanus cajan* (L.) Millspaugh). The drought tolerant legume is grown mainly in the semi-arid tropics though it is well adapted to several environments. The crop represents about 5% of world legume production.

As part of our efforts to promote dietary diversification and increased utilization of orphaned crops to promote good nutrition and wellbeing, we investigated the pigeon pea potential as a food/feed ingredient for use among the rural poor. African Pigeon pea was found to be abundant in protein and lower in anti-nutritional factors compared with other legumes, making it an ideal supplement to traditional cereal-, banana- or tuber-based diets of most Africans which are generally protein-deficient (Ologunde *et al.*, 2004). The supplementation of cereals with protein rich legumes is considered one of the best solutions to protein-calorie malnutrition in the developing world. Pigeon pea flour has been tested and found to be suitable as a protein source for supplementing baked products and has been recommended in school feeding programs. Pigeon pea is a nutrient-dense food containing more minerals, ten times more fat, five times more vitamin A and three times more vitamin C than ordinary peas. Wide adoption of pigeon pea in Africa thus stands to play an important role in food security, balanced diet and alleviation of poverty.

On the strength of the foregoing, I decided to evaluate the digestibility of the native Nigerian *Cajanus cajan* including processing methods employed to reduce level of toxicants in the meal as a step towards promoting its utilization in situations of protein-energy or protein-calorie malnutrition in Nigeria (Ologunde *et al.*, 2004). Thus, in the study titled 'Serum Biochemical changes associated with the digestibility of *Cajanus cajan* seeds in rats', interesting results were obtained. In a metabolic study with rats (Ologunde *et al.*, 2004), I observed that nutritional benefits measured in terms of protein efficiency ratio (PER) were highest at 87% inactivation of the anti-nutritive components. I also observed that protein quality was synergistically improved in cereal-legume mixes because of the lysine contributed by the *Cajanus cajan* and the methionine contributed by the maize. An enhancement of PER with blanching over roasting was observed which in my opinion was due to lack of caramelization in the former. Overall, I noted that the process parameters and formulations developed in this study successfully produced a high protein-energy rich food for the feed industry. These processing steps have been documented and are available for commercialization of the seeds.

Table 8: Protein components of *Cajanus cajan* based diet and their effect on rats consumption pattern

Diets Based on <i>Cajanuscajan</i>	Protein %	Initial weight (Nx6.25) (g)	Final weight (g)	Weight Gain (g)	Food Intake	Protein Consumed (g)	PER
*Control	15%	48.10±2.40	124.90±3.62	76.80±1.26	201.60±3.26	30.24±1.10	2.54±0.30
BASAL (RAW SEEDS)	15%	46.00±2.21	37.43±1.22	(-8.57)	87.21±1.42	13.08±0.92	(-0.66)
I: roasted at 60°C for 25mins	15%	43.46±2.82	61.78±2.22	18.32±0.92	127.2±2.80	19.08±1.28	0.96±0.00
II: roasted at 60°C for 50mins	15%	44.60±3.24	79.18±2.84	34.58±1.66	180.18±3.21	27.02±0.96	1.28±0.01
60°C for 150mins	15%	45.20±1.22	86.20±1.80	41.00±1.07	192.10±2.78	22.82±1.28	1.42±0.02
IV: blanched for 25mins	15%	44.13±2.08	67.49±2.80	23.36±2.01	146.93±1.93	22.04±1.11	1.06±0.02
V: blanched For 50mins	15%	46.3±2.56	79.31±3.2	33.01±2.11	168.00±2.96	25.20±0.76	1.31±0.05
VI: blanched For 150mins	15%	45.21±3.26	95.19±2.1	49.98±1.24	189.33±2.65	28.40±0.28	1.76±0.20

Values are means of 4 determinations ±SD; *Commercial formula; Nutrend; PER- protein efficiency ratio

Source : Ologunde, M. O., Farinu, G.O. and Babalola, A.O. (2004). Serum Biochemical Changes Associated with the Digestibility of Raw and Heat Processed *Cajanuscajan* Seeds in Rats. Nigerian Journal of Natural Products and Medicine, 9: 24-29.

Table 9: The effect of *Cajanus cajan* based diets on rat organ weight

Diets Based on <i>Cajanuscajan</i>	Animal weight (Final 9g)	Liver	Kidney	Heart
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		Weight	% Body weight	Weight	% Body weight	Weight	% Body weight
*Control	124.90±3.62	6.98±0.00	5.60	0.48±0.06	0.60	0.16±0.00	0.20
BASAL (RAW SEEDS)	37.34±1.22	1.80±0.01	4.81	0.38±0.07	0.14	0.11±0.00	0.04
I: roasted at 60°C for 25mins	61.78±2.22	2.88±0.06	4.66	0.42±0.09	0.26	0.10±0.00	0.06
II: roasted at 60°C for 50mins	79.18±2.84	3.89±0.12	4.92	0.43±0.10	0.34	0.11±0.00	0.09
III: roasted at 60°C for 150mins	86.20±1.80	4.32±0.26	5.01	0.44±0.10	0.34	0.13±0.00	0.11
IV: blanched for 25mins	67.49±2.80	2.56±0.11	3.80	0.43±0.03	0.29	0.11±0.00	0.70
V: blanched for 50mins	79.31±3.20	3.34±0.10	4.21	0.44±0.00	0.35	0.13±0.00	0.10
VI: blanched for 150mins	95.19±2.10	4.25±0.46	4.46	0.46±0.00	0.44	0.15±0.00	0.14

Values are means of 4 determinations ±SD; *Commercial formular; Nutrend;

SOURCE :Ologunde, M. O., Farinu, G.O. and Babalola, A.O. (2004). Serum Biochemical Changes Associated with the Digestibility of Raw and Heat Processed Cajanuscajan Seeds in Rats. Nigerian Journal of Natural Products and Medicine, 9: 24-29.

NUTRIENT BIOAVAILABILITY

A major factor that causes and promotes malnutrition is the presence of anti-nutritional factors in foods. These anti-nutritional factors serve as nutrients inhibitors and toxic substances. Anti-nutritional factors can be classified broadly as those naturally present in the grains and those due to contamination which may be of fungal origin or may be related to soil and other environmental influences. These factors modify the nutritional value of the individual food grains, and some of them have very serious consequences on the health of the consumers (FAO, 1995). Thus some of my research efforts were geared towards reducing the anti-nutritional components of foods to increase nutrient bioavailability.

What then is nutrient bioavailability?

Bioavailability is the ease with which any nutrient is released from the food matrix into the body after eating. The mode of nutrient release is identical. Firstly, the food matrix must be broken down commencing with mastication in the mouth followed by the intervention of different classes of enzymes, in the mouth, stomach, duodenum and finally in the intestine. Once the nutrient has been freed, the next stage is absorption and this takes place in the small intestine, transportation is via the hepatic portal vein to the liver and from there to the rest of the body. When a nutrient is highly bioavailable, it can be digested and absorbed in high percentage of the time. This occurs when contaminant concentration is low. However, when a nutrient is poorly available, its digestion, absorption or both can be more difficult and less dependable.

Plant foods are the major staples of diets in developing countries, in which the consumption of animal-source foods is often low because of economic and/or religious concerns. However, such plant-based diets are often associated with micronutrient deficits, exacerbated in part by poor micronutrient bioavailability. Diet-related factors in plant foods that affect bioavailability include: the chemical form of the nutrient in food and/or nature of the food matrix; interactions between nutrients and other organic components (e.g. phytate, polyphenols, dietary fibre, oxalic acid, protein, fat, ascorbic acid); pretreatment of food as a result of processing and/or preparation practices. For example, tannins affect palatability, reduce food intake and consequently body growth. It binds to both exogenous and endogenous proteins including enzymes of the digestive tract, affecting the utilization of proteins (FAO, 1995). Phytate occurs as a mineral complex, which is insoluble at the physiological pH of the intestine. It is considered anti-nutritional, causing reduced uptake in the human intestine of essential dietary minerals such as Fe, Zn, Mg and Ca and make dietary minerals unavailable for absorption and utilization by the body (Sandberg, 2002). It can also form complexes with proteins, proteases and amylases of the intestinal tract, thus inhibiting proteolysis.

A consideration of the relevance of the above especially in infant nutrition prompted the study carried out on iron bioavailability in the native Nigerian grain amaranth which is being proposed as a food vehicle of iron fortification in the coming years.

Although grain amaranth is a rich source of minerals, its iron content estimated at 6.90mg/100g grain flour) may not be available because of the negative influence of both phytate and tannin on iron absorption and nutrient digestibility. Considerable research has confirmed that iron deficiency within population groups is caused not only by inadequate iron intake but also by interactive factors that adversely affect dietary iron bioavailability (Patwardhan, 1961). Dietary phytate has been shown to chelate metallic ions thereby making iron unavailable (Hallberg *et al.*, 1987). Phytate may also bind minerals in the gastro intestinal tract, further inhibiting iron absorption (Oberleas, 1983). Tannin reduce protein digestibility, either by deactivating digestive enzymes or by reducing the susceptibility of the substrate proteins after forming complexes with tannins and absorbed ionizable iron. Bressani *et al.* (1987) investigated these inhibitors and found that 33 raw Guatemalan grain amaranth samples average 0.417% tannic acid and 2.05 UTI cm⁻³ trypsin, but the bioavailability of iron in cooked native Nigerian grain amaranth samples has not been previously evaluated.

Consequently if amaranth grain flour is to be used as a staple food, most especially for infants and children in the third world, it is appropriate to assess it for iron bioavailability and fortification. We decided to evaluate these two properties.

The summary of the results obtained are contained in Table 10:

Table 10: Comparison of bioavailability of iron fortification compounds in grain amaranth cereal^a

	Grain amaranth without iron fortification	Fortified grain amaranth			Casein diet fortified with FeSO ₄	P value	LSD ^f
		NaFeEDTA	FeC ₄ H ₄ O ₂	FeSO ₄			
	A	B	C	D	E		
PER	1.7±0.1g	1.6±0.1	1.6±0.1	1.6±0.1	2.2±0.1	0.467	NS*
TIBC, change (% final)	25±1	55±1	67±2	55±2	52±1	0.001	3
Serum iron, initial (µ/dl)	36±3	38±3	39±3	44±3	41±2	0.34	NS
Serum iron, final(µ/dl)	51±2	76±5	84±15	71±9	74±5	<0.001	27
Liver weight (g)	4.1±0.1	4.0±0.1	4.1±0.1	3.8±0.1	4.4±0.2	0.313	NS
Non-haem liver iron (µg/g)	20.4±1.5	43.1±6	55±8	31±4	25±0.2	0.002	15.5
Non-haem liver iron (µg)	83.6±0.8	172±4±0.03	225.5±2	118±2.6	110±1.8	0.002	61
RBV ^d	0.40±0.01	1.55±0.03	1.75±0.04	1.67±0.02	1.00±0.02	<0.001	0.08
RbBV ^e (adjusted)	0	1.15±0.01	1.35±0.02	1.27±0.01	1.00±0.02	<0.001	0.1

^a10 animals per group were fed the test diets containing 35mg fortification Fe/Kg diet during the 7days repletion perios,except group A

^bAmount of native iron present in feed

^cHb Fe gain/Fe intake x 100

^dRBV calculated by mean Hb gain of test Fe source divided by mean Hb gain of FeSO₄-fortified casein diet

^eRBV calculated as above by discounting Hb contributed by native iron in cereal

^fMeans differences must equal or exceed the least significant difference (LSD) value to be significantly different at the 0.05 probability level

^gMeans ± SEM

NS = not significantly different.

SOURCE: Ologunde, M. O., Shepard, R. L., Afolabi, A.O., and Oke, O. L. (1991). Bioavailability to Rats of Iron from fortified Grain Amaranth Flour. *International Journal of Food Science and Technology*. 26: 493-500.

Based on the results above, we demonstrated the relative stability and high Relative Biological Value (RBV) of ferrous fumarate and ferrous succinate when used as fortificants in infant cereals based on both human and animal studies. It was not surprising that ferrous fumarate had the highest RBV (1.75 ± 0.04 vs. 1.00 ± 0.00 casein control) in this study.

I concluded as follows:

Grain amaranth processed as in this study maintained:

- A favourable PER value for a vegetable product,
- RBV for the amaranth diet alone was low (0.4 ± 0.01) indicating poor iron absorption from the native iron source.
- Animal groups receiving iron fortification showed a significant increase in Hb Fe gain, Hb gain, Fe availability, Total iron binding capacity (TIBC) and serum iron.
- These increases compared well with that of FeSO_4 -fortified casein meal used as standard.

Based on the results of this study, it appeared that:

- A cereal-based infant weaning food composed of grain amaranth would be useful as a food vehicle for iron fortification to reduce the incidence of iron deficiency anaemia especially in infants.
- It can also serve as an intervention strategy to combat protein-calorie malnutrition in infants and young children in the third world.
- Native phytate and tannin in the grain had no effect on fortified iron.

FOOD FORTIFICATION

Arising from the study above, I decided to examine the issue of food fortification. Having observed the inhibitory roles of some constituents of the plant towards good nutrition and also the fact that some essential nutrients (both micro and macro) might be lost in the course of processing, I propose that for purposes of wholesomeness of the food, the estimated quantity of nutrients lost must be replaced. If micronutrients are the ones lost in the course of processing a situation of micronutrient malnutrition would result. This is by far the greatest form of human malnutrition. It is popularly referred to as hidden hunger.

WHAT IS FORTIFICATION?

Fortification is a food-based approach to optimize nutrition where there is dependence on staples and a narrow range of foods. Fortification is not all the same and may be:

- Chemical fortification (e.g. Blending). This is more common.
- Biofortification (e.g. Plant breeding).

Fortification most times affects micronutrient deficiency or hidden hunger. Generally, there are three methods of addressing this. These are:

- Supplementation
- Food Fortification and,
- Dietary Diversification.

HIDDEN HUNGER

This is an invisible problem with grave consequences. We automatically associate hunger with not having enough to eat. We have all seen images of acutely undernourished people in disaster areas. Almost one billion people around the world are undernourished. However, not having enough to eat is only part of the problem of hunger. What experts refer to as 'hidden hunger' attracts less attention because it does not produce dramatic images, yet while it has gone largely unnoticed, it has assumed dramatic proportions. Two billion people are now affected by it – almost a third of the world's population (FAO/WHO, 1998).

This hidden form of malnutrition is caused by a deficiency of vital micronutrients (vitamins, minerals and trace elements) in the body. These micronutrients are essential to the mental and physical development of both children and adults. Vitamin A-deficient infants, for example, are at risk of infection, visual impairment and higher mortality rates. Anaemia caused by an iron deficiency

impairs the ability of school-age children to learn and reduces adults' ability to work and lack of attention span. The symptoms of vitamin and mineral deficiencies are still largely ignored in national health systems and in bilateral development cooperation, despite the fact that hidden hunger not only impacts on health but also comes at a high economic price.

Evidence-based solutions for reducing hidden hunger

The World Health Organization has carried out research to generate data for individual countries about the extent of vitamin A, iodine and iron deficiency forming the basis for general recommendations for at-risk groups and the broader population. **At-risk groups include women of child-bearing age, newborns and infants, the sick and elderly. They also include those in emergency situations, such as refugees or internally displaced persons (IDPs), who do not have reliable access to adequate nutrition.**

There are three main types of intervention to prevent and combat vitamin and mineral deficiencies, which can be deployed individually or in combination: short-term supplementation; medium-term food fortification; and a long-term focus on balanced nutrition (dietary diversification). The latter, being the most economical and within the income level of the rural dwellers is discussed.

I. Supplementation

Food supplements are highly concentrated vitamins and minerals produced by pharmaceutical manufacturers in the form of capsules, tablets or injections and administered as part of health care or specific nutrition campaigns. Medical staffs working for national health services, supported by organizations such as UNICEF, distribute vitamin capsules, iodine and iron tablets widely to infants, women of child-bearing age and women who have given birth without prior assessment of their individual needs. The greatest cost-benefit effect comes from giving supplementary Vitamin A to children under the age of two, because the damage caused by micronutrient deficiency in the early years of life is irreversible. The United Nations' 'Scaling Up Nutrition' (SUN) initiative refers to the unique 'window of opportunity' represented by an individual's first thousand days of life, starting from conception. However, older people, displaced persons and refugees may also suffer specific deficiencies.

II. Food fortification

The approach here is to fortify food with essential nutrients. The United Nations Food and Agriculture Organization recommend that governments in countries with high malnutrition rates consider fortifying food with iodine, iron and vitamin A in particular and that they regulate fortification (FAO, 1995). The UN's Codex Alimentarius Commission lays down international food standards, which list the basic conditions for national fortification programme:

- (in)direct evidence of an appropriate rate of malnutrition;
- Identification of a food carrier/ vehicle (such as flour or edible oil) that is consumed by the whole of the malnourished population and whose consumption is recorded; and
- An evidence base for minimum and maximum fortification rates (FAO, 1996).
- Food fortification is attractive because it does not require the target groups to change their diet but can be implemented by the food industry because it reaches large numbers of consumers through retail. It is a particularly effective way of tackling deficiencies in densely populated urban areas. Mandatory labelling tells consumers that the food they are buying has been fortified, while accompanying 'social marketing campaigns' are often effective.

III. Dietary diversification/ Bio-fortification

The density of minerals and vitamins in food staples eaten widely by the poor may be increased either through conventional plant breeding or through use of transgenic techniques, a process known

as bio-fortification. Identified plant species include: orange-skin sweet potato and cassava, pearl millet, maize and rice. These are plants already ascertained to be high in iron, zinc and pro-vitamin A.

Bio-fortified crops offer a rural-based intervention that, by design, initially reaches these more remote populations, which comprise a majority of the undernourished in many countries, and then penetrates to urban populations as production surpluses are marketed. In this way, bio-fortification complements fortification and supplementation programs, which work best in centralized urban areas and then reach into rural areas with good infrastructure. Initial investments in agricultural research at a central location can generate high recurrent benefits at low cost as adapted bio-fortified varieties become available in country after country across time at low recurrent costs. This programme is an interdepartmental collaborative research presently being undertaken in this university.

Other strategies to Combat Micronutrient Malnutrition:

- ✓ Food Technology
- ✓ Food product development
- ✓ Nutrient supplementation
- ✓ Nutrition education

Table 11: Micronutrient Deficiencies and Effects

Nutrient Insecurity and Micronutrient Deficiency	<ul style="list-style-type: none"> • Impairs mental and physical development of 40-60% of infants in developing world. • Debilitating the health and energy of about 500 million women. • Leads to the death of about 60,000 women during child birth every year. • Nutritional anemia affects nearly half of all children globally and an estimated 1.6 million people worldwide.
Vitamin A	<ul style="list-style-type: none"> • Affects 40-60% of children under five in developing countries, compromising their immune system, resulting in a million deaths every year. • Worldwide 5 million children under the age of 5 are affected by a serious eye disorder, xerophthalmia that makes them vulnerable to becoming blind, as a result of vitamin A deficiency.
Child Stunting	<ul style="list-style-type: none"> • Approximately one-third of children worldwide suffer from stunted growth due to poor nutrition; this results in them being underweight and leads to impaired mental and physical development and increase the risk of chronic diseases.
Iodine Deficiency	<ul style="list-style-type: none"> • It is the world's greatest cause of mental retardation and brain damage. It lowers the intellectual capacity by 10-15 points.
Folate Deficiency	<ul style="list-style-type: none"> • It is responsible for 200,000 severe birth defects every year. • It is associated in 1 in every 10 deaths from diseases in adults.

SOURCE :FAO/WHO, 1999

IODINE DEFICIENCY DISORDER (IDD)

Nutritionists estimated that about one billion people or 12% of the world's population are at risk of iodine deficiency, and that 20-30% of the people at risk show signs of deficiency (ICC/IDD, 2002). The deficiency in iodine manifests in different people, in various forms of disorders and these are generally termed iodine deficiency disorder (IDD). IDDs include such diseased conditions as goiter, irreversible mental retardation, reproductive failure, increased child mortality and cretinism. IDDs occur when people are iodine deficient either when there is lack of iodine in the dietary intake or when the diet also contains some detrimental levels of goitrogens such as linamarin found in raw cassava or improperly processed cassava products (Oke, 1987). These compounds react with available iodine in the body to deplete the body store of the chemical (Osuntokun, 1969). The resultant effect stresses the thyroid gland to over produce and which in effect results in the enlargement of the gland, popularly referred to as goiter.



PLATE 3: Different forms of iodine deficiency disorders (IDDs)

Iodized salt is acclaimed as one of the best food vehicles of delivering iodine to iodine-deficient populations. It is physiologically simple, practical and effective. It has been used all over the world with success. The CODEX ALIMENTARIUS standards (1982) permit a level of fortification that ranges from 30 to 200 ppm, which will provide enough iodine to meet the requirement of 150 to 200 ug per person per day.

In Nigeria, although iodized salt has been commercially available, its use became mandatory only in the very recent past. There is limit to salt intake that could address serious iodine deficiency occasioned by cassava-cyanide toxicity without impairing serious electrolyte balance of the body. Cases of high blood pressure consequent on high salt intake have been reported in adults.

Consequently, the nutritional option of using a high protein fortified meal as a food vehicle of iodine fortification was suggested. Since this approach had not been used before it had to be experimented. Hence, we decided to try with Ogi (made from cereal, corn) fortified with Soy flour. Our choice of soy flour was based on:

- Nutritionally, it is a rich and relatively cheap source of protein (about 40%) and more accessible than animal protein;
- It is a low calorie, low carbohydrate food with the ability to increase fat cell metabolism and preserve lean body mass;
- It is rich in fibre, empowers glucose tolerance, cholesterol-free, with very low levels of saturated fat, high polyunsaturated fatty acids (about 85%), rich in vitamins, and contains beneficial phytochemicals, such as isoflavones that protect against cancer.

The effectiveness of Soy-Ogi as a food vehicle of iodine fortification was thus tested in our laboratory using a rat bioassay. Iodine deficiency was induced by feeding male albino rats on high cassava diet (8.58mg/100g cyanide content) for a prolonged period during which animals exhibited

neurological symptoms. Iodine deficient rats were later placed on a repletion diet made up of soy-ogi fortified with iodine at two concentrations of 35ppm and 70ppm respectively. After 42 days on the repletion diet, animals were killed by decapitation following chloroform anesthesia and blood collected.

Haematological parameters including haemoglobin concentration, serum protein albumin, glucose, red and white blood cell counts, alkaline phosphatase activity, SGPT, SGOT as well as packed cell volume were all determined and values obtained. Plasma albumin, one of the more sensitive indicators of protein nutritional status was comparable for all the animals. Red blood cell counts averaged $10 \times 10^{12} \text{dm}^{-3}$. Levels in the animals were above average and were comparable with values obtained for the animals on control diet. The PCV values were all above human cut-off levels and confirm, with the haemoglobin levels, that the fortified diets were adequate to prevent anaemic conditions over the periods studied. With a PER above 2.1 (control had 2.6) the approach was considered feasible more so with the meal targeted at infants and children.

Organoleptic assessment carried out confirmed that the product, in spite of the fortification with iodine at the two concentrations (35ppm and 70ppm) was acceptable in terms of taste, colour and general acceptability and hence could be recommended as an intervention strategy in situations of perceived iodine malnutrition where endemic goiter is prevalent.

The processing parameters are well documented. The information on use of soy fortified Ogi as a food vehicle for iodine fortification is made available for the first time in literature

Table 12A: Nutrition Data

	Mean Weight Gained (g)	Average Food Intake (g)	Protein Intake (g)	PER	Corrected PER
Infant formula (Control)	36.82 ± 0.80	82.45 ± 1.00	15.60 ± 0.98	2.36 ± 0.00	0.44 ± 0.00
Diet A	30.98 ± 0.60	76.77 ± 3.20	14.28 ± 0.00	2.17 ± 0.02	0.40 ± 0.00
Diet B	29.20 ± 0.55	70.42 ± 2.60	13.52 ± 0.19	2.16 ± 0.02	0.41 ± 0.00

Values are means of four determinations ±SD

Source: Ologunde M. O. and Oyadare, A. O. (2005). Effectiveness of Soy-Ogi as a Food Vehicle of Iodine Fortification. Journal of Agriculture, Food Technology and Environment. 7(1): 38-43.

Table 12B: Haematological data on test animals fed different fortified diets

	PCV%	Red Cell ($\times 10^{12}/\text{dm}^3$)	White Cell ($\times 10^9/\text{dm}^3$)	Haemoglobin (g/dm^3)
Control	46 ± 0.5	10.7 ± 0.00	7.9 ± 0.00	16.4 ± 0.00
Diet A	48 ± 0.1	10.0 ± 0.00	6.2 ± 0.00	17.3 ± 0.00
Diet B	48 ± 0.1	10.0 ± 0.00	6.4 ± 0.00	17.4 ± 0.01

Values are means of four determinations ± SD

Source: Ologunde M. O. and Oyadare, A. O. (2005). Effectiveness of Soy-Ogi as a Food Vehicle of Iodine Fortification. Journal of Agriculture, Food Technology and Environment. 7(1): 38-43.

Table 12C: Blood Chemistry Parameters

	Residual Cyanide Conc. ($\mu\text{g}/\text{cm}^3$)	Blood Iodine Conc. ($\mu\text{g}/\text{dm}^3$)	SGPT (IU/ dm^3)	Serum Albumin Alkaline (g/dm^3)	Serum Phosphatase (IU)
Control	0.00 ± 0.00	0.50 ± 0.00	4.40 ± 0.00	6.03 ± 0.01	2.00 ± 0.00
Diet A	0.05 ± 0.00	2.24 ± 0.21	7.28 ± 0.00	4.43 ± 0.10	4.00 ± 0.20
Diet B	0.06 ± 0.00	4.80 ± 0.22	7.01 ± 0.00	4.07 ± 0.00	6.00 ± 0.70

Values are means of four determinations ± SD

Source: Ologunde M. O. and Oyadare, A. O. (2005). Effectiveness of Soy-Ogi as a Food Vehicle of Iodine Fortification. Journal of Agriculture, Food Technology and Environment. 7(1): 38-43.

SPAGHETTI FORTIFIED WITH VEGETABLE PROTEIN SOURCES

One of the food-based strategies for preventing macro and micronutrient malnutrition is the addition of nutrients to commonly eaten foods to maintain or improve the quality of the food item (WHO/FAO, 2006). The fortification of an inexpensive and easy-to-cook food such as spaghetti is a practical intervention strategy that could provide the most reliable method for achieving long-term enhancement of protein status especially in infants and may therefore be recommended as an intervention strategy.

As a consequence of the above, we decided to investigate the possible enhancement of the food quality of spaghetti products with vegetable sources. This was another effort aimed at demonstrating our ability to produce fortified food products for the consumption of the malnourished populace. Protein enhancement of spaghetti products with vegetable meal sources that included melon, groundnut and Soya bean was carried out long before commercial advertisement of the same was proposed through fortification. The effects of the addition were evaluated in an animal model experiment. Nutritional, biochemical and sensory parameters of the new products were examined.

Results showed that of the three fortificants used; only soybean gave a percent mean weight (86.70 ± 4.15) above that of control (75.54 ± 2.41). The mean protein efficiency ratio (PER) obtained for soybean (1.75 ± 0.00) was statistically different ($p < 0.05$) from control (1.04 ± 0.00). Feeding spaghetti alone gave the poorest percent weight gain of 19.8 ± 1.64 and a mean PER of 0.51 ± 0.01 that was below that of the control. Serum protein content a sensitive indicator of protein nutritional status was consistent with these findings. Panelists preferred spaghetti fortified with soy bean over that fortified with groundnut or melon seed. In most cases the mouth feel of spaghetti fortified with soybean decreased with storage. However, general acceptability of the product was not affected. On the basis of nutritional and biochemical data, spaghetti fortified with soybean was preferred.

I and my students did extensive study of food contamination in locations affected by the processing of crude oil in the Niger Delta. Our reports are presented below.

CONTAMINATION OF WATER AND AGRICULTURAL FOOD RESOURCES IN CRUDE OIL PROCESSING LOCATIONS

CHEMICAL CONSTITUENTS OF CRUDE OIL

The effluent from crude oil exploration and processing consists of oil and an assortment of chemicals that include hydrocarbons, heavy metals and other toxic compounds, substances that have been proven to be carcinogenic in nature. Some of these include: Decane ($C_{10}H_{22}$), Tetradecanes ($C_{14}H_{30}$), Hexadecane ($C_{16}H_{34}$), Tetracontane ($C_{40}H_{82}$), Triacontane ($C_{30}H_{62}$), Ashalterie ($C_{80}H_{162}$) The release of these contaminants especially from produced water and gas flared has polluted potable water sources, contaminated agricultural land and raw materials, destroyed fishery resources and created general adverse socio-economic consequences in the environment (Ologunde, 2004).

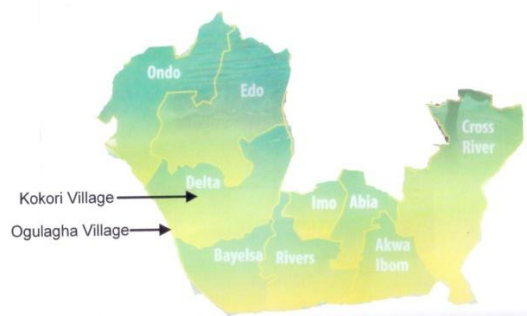


PLATE 4A: OIL PRODUCING STATES OF THE



PLATE 4B: SAMPLING LOCATIONS

SOURCES OF CONTAMINATION OF THE ENVIRONMENT.

Gas flaring, crude oil spills and produced water are the major are the major sources of chemical contaminants identified. Gas flaring creates perpetual heat and emission of poisonous gases. Equally important is the problem of acid rain that is a common occurrence in the Niger Delta. It is associated with forest decline near shore areas. Acid rain, i.e. rain with a pH of 5.6 or lower has been known to cause deforestation, loss of soil fertility, destruction of aquatic resources and other forms of primary producers.

Humphrey (1988) observed that acid rainfall injures vegetation, and acidifies lakes, streams and soil. As a major global problem, acid rain can destroy aquatic life and slow down forest growth. It is associated with forest decline in crude oil processing communities.

EFFECTS OF GAS FLARING

The natural gas flared off contains many contaminants. Chronic low levels and prolonged exposure comes with a terrible cost on human health. The cost is to the inhabitants of the neighbouring villages who live and farm in proximity to a flaresite (see Plate 5). The communities are exposed where they sleep and eat as wind carries the fume of the combustion products. The potential adverse human health impact and implications are on the natural environment and natural habitat of blood (haemopoetic system) which is the most important system in all organisms in state of both health and diseases. Blood cells transport foreign contaminants to different organs which expose the system to a variety of diseases and cancer such as cardiovascular, respiratory, reproductive, neuro degenerative and kidney dysfunctions. It is significant to say that some of these contaminants enter the body through the skin, lungs or gastrointestinal tract.



PLATE 5: IMAGES OF GAS FLARING. SOURCE: INTERNET PHOTOGRAPH.

The general ecological impact of oil spills include:

- (i) Destruction of phytoplankton population. Decrease of fishery resources and damage to wildlife such as seabirds, marine animals, etc.
- (ii) Human hazards arising from the consumption of contaminated sea foods and food raw materials harvested from polluted sites.

The harmful effects of oil spills on the environment are many. Oil kills plants and animals in the estuarine zone, settle on beaches and kill organisms that live there. It also settles on ocean floor and kills benthic (bottom-dwelling) organisms such as crabs. Oil poisons algae, disrupts major food chains and decreases the yield of edible crustaceans. It also coats birds' feathers, impairing their flight or reducing the insulative properties of their feathers thus making the birds more vulnerable to cold (Plate 6). Oil endangers fish hatcheries in coastal waters and as well as contaminates the flesh of commercially valuable fish (Val and Almeida-Val, 1999).

Most of the landed areas in oil producing areas of Nigeria are used for cultivation because the main occupation of people living in the region is farming and fishing. In land used for agricultural purposes, petroleum or diesel-contaminated wastes and accidental spills of crude oil at some drilling sites pose exposure risks for occupational public, livestock and wildlife. The petroleum hydrocarbons can eventually get into man and animals through ingestion of contaminated food or bioconcentration through the food chain (Jessup and Leighton, 1996).



PLATE 6: IMAGES OF CRUDE OIL SPILL. SOURCE: INTERNET PHOTOGRAPH

In a series of simulated animal bioassay studies to establish the effect of gas flaring and oil spillage (Ologunde and Adeyemi, 2005), Wistar litter mate rats were fed with crude oil polluted diet collected from spill areas (Kokori and Ogulaga) which remained uncleaned for six months. The proximity of these locations to Forcado Terminal and Tank Farm were factors considered in their choice. The following results presented in Tables 13 to 18, Plate 7 and Fig 3 were obtained from the animal bioassay studies carried out.

TABLE 13: BODY WEIGHT GAIN OF RATS (g)

Weeks	0	3	6	9	12	13	Weight gain (g)	Gain (%)
Diets I	260.0±5.2	289.6±7.5	318.6±16.6	353.8±11.3	399.9±7.0	403.9±8.1	143.9	55.4
Diets II	250.0±5.0	274.2±8.2	299.3±3.3	326.5±3.3	344.3±10.1	343.7±7.5	93.7	37.5
Diets III	255.5±2.1	277.6±3.2	305.8±9.6	336.2±5.6	360.9±12.1	369.9±8.2	114.4	44.8
Diets IV	252.3±7.1	275.4±6.5	289.0±8.2	311.3±7.0	321.6±11.2	322.7±9.4	70.4	27.9

Values are means of 4 determinations±SD

SOURCE: Ologunde, M. O. (2005) Crude-Oil contamination of local food sources – A study of Selected locations in the Niger Delta area, Ph.D Thesis, Ladoké Akintola University of Technology, Ogbomosho.

A depressed growth pattern was observed for experimental diets when compared against the control. Similar observation was noted by Chu *et al.* (1990). The authors identified a ‘feed refusal’ factor that hindered feed utilization by the animals. However, values were in general agreement with weight gain in similar studies carried out to test the effect of organochlorine compounds on laboratory animals.

EFFECTS ON HAEMATOLOGICAL INDICES

Exposure of the animals to prolonged feeding on crude oil contaminated diet adversely affected the haematological parameters. Chronic exposure leads to a drastic decrease in the following blood parameters: packed cell volume (PCV), haemoglobin concentration [Hb] and red blood cell count (RBC) compared with animals on control diet. The increase in cholesterol along with a decrease in packed cell volume is in tandem with increase in protein observed. The chemical toxicant might have affected the liver to stimulate synthesis of and excretion of protein into the serum. In several organs, cell damage was followed by release of a number of cytoplasmic enzymes into the blood, a phenomenon that provides the basis for clinical diagnosis (Sunderberg *et al.*, 1994). There was a drastic increase in white blood cell count (WBC) which is an indication of degenerative disease condition. Glucose-6 phosphatase activity was observed to take a downward trend by the seventh week for all test diets indicating perhaps some damage to compartments holding the enzyme. In similar vein, the following enzymes: SGOT, SGPT, Alkaline phosphatase and creatinine were assayed and their activities determined. The outcome is reflected in Table 16.

TABLE 14: BLOOD CHEMISTRY

	Glucose mg/100cm ³	PCV (%)	Protein mg/100cm ³	Cholesterol mg/100cm ³	Inorganic Phosphate mg/100cm ³	Haemoglobin (g/dl)
Diets I	162.2±1.3	41.3±1.93	16.8±0.2	43.2±1.0	5.9±0.2	19.1±5.5
Diets II	272.9±0.9	38.5±2.5	15.9±0.2	117.9±1.6	9.9±1.0	17.9±5.1
Diets III	232.8±4.4	39.3±3.7	17.4±0.1	94.6±1.0	9.7±0.9	18.7±5.6
Diets IV	309.6±10.0	40.0±3.9	18.1±0.2	50.8±0.5	4.6±0.0	15.8±4.7

Values are means of 4 determinations ± SD

SOURCE: Ologunde, M. O. (2005) Crude-Oil contamination of local food sources – A study of Selected locations in the Niger Delta area, Ph.D Thesis, Ladoké Akintola University of Technology, Ogbomosho.

BODY WEIGHTRATIO OF ORGANS

Body weight ratio of organs is an indication of stress reaction in the form of an increase in body weight ratio of some organs and loss in weight of some others relative to the weight in control animals. There was slight increase in weight of the cardiac stomach and small bowel due mostly to a marked increase in water content

of the organ although this was not reported. Increased in liver weight has been observed in rats after short-term treatment with coal co-processing products (Chu *et al.*, 1991). Liver enlargement was also reported following inhalation exposure to coal liquefaction products (Springer *et al.*, 1986). The increase in kidney/body weight ratio was similar to that reported for animals treated sub chronically with coal coprocessing products (Chu *et al.*, 1991). The observation of an increase in absolute spleen weight as well as spleen/body weight ratio in diet IV and the high incidence of abnormal spleen morphology found at necropsy indicated that the chemical toxicant in diet IV affected the spleen to a greater extent than in diets II and III. Poon *et al.* (1996) observed that the coal liquefaction products and coal co-processing products being chemicals also consist of complex mixture of aliphatic, aromatic and nitrogen-containing organic materials.

Looms (1998) showed that the weight of certain organs of the body is more constant than the body weight. These organs include brain, kidney and liver. Consequently any shift in weight of these organs is a manifestation of an adverse reaction in the animal. The observed differences in body weight ratio especially in diet IV may perhaps be due to the significant presence of the chemical pollutant and hence an indication of the damage caused by the chemical pollutant. This effect is further amplified by the outcome of the assay of glucose-6-phosphatase (Fig 3).

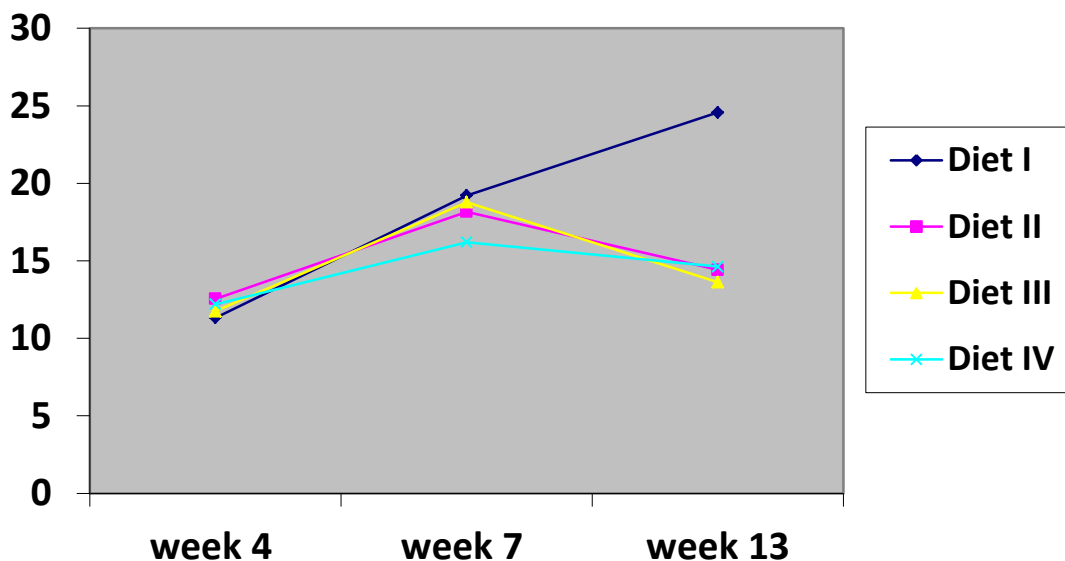
TABLE 15: WEIGHTS OF ORGANS AS PERCENTAGE OF BODY WEIGHT OF ANIMAL

	Animal		Liver		Kidney		Heart		Brain	
	Weight	Weight	%BW	Weight	%BW	Weight	%BW	Weight	%BW	
Diets I	299.7±9.0	4.97±0.62	1.91±0.03	1.10±0.15	0.42±0.03	0.63±0.32	0.24±0.0	1.51±0.12	0.58±0.01	
Diets II	283.8±6.0	5.55±0.25	2.22±0.02	1.23±0.36	0.49±0.02	0.66±0.12	0.26±0.01	1.64±0.11	0.66±0.03	
Diets III	288.5±4.8	5.49±0.85	2.15±0.02	1.17±0.22	0.45±0.01	0.50±0.01	0.23±0.00	1.71±0.07	0.67±0.01	
Diets IV	280.9±3.0	6.05±0.47	4.40±0.04	1.29±0.22	0.51±0.01	0.63±0.02	0.25±0.01	1.78±0.02	0.71±0.01	

Values are means of 4 determinations±SD

SOURCE: Ologunde, M. O. (2005) Crude-Oil contamination of local food sources – A study of Selected locations in the Niger Delta area, Ph.D Thesis, Ladoke Akintola University of Technology, Ogbomoso.

Figure 3: Glucose-6-phosphatase activity in liver of rats fed on control and experimental diets



SOURCE:

Ologunde, M. O. (2005) Crude-Oil contamination of local food sources – A study of Selected locations in the Niger Delta area, Ph.D Thesis, Ladoke Akintola University of Technology, Ogbomoso.

TABLE 16: SERUM ENZYME ANALYSIS

		SGOT	SGPT	ALKALINE P ASE	CREATININE
DIET I CONTROL	SHORT TERM	187.78±3.87	102.68±6.35	244.17±4.57	1.01±0.01
	LONG TERM	210.41±4.56	128.08±6.42	280.80±12.26	1.17±0.05
DIET II	SHORT TERM	277.53±6.15	258.04±11.60	391.81±12.10	2.19±0.44
	LONG TERM	316.38±10.22	291.64±6.21	450.58±14.36	2.54±0.21
DIET III	SHORT TERM	260.72±5.69	156.77±5.32	452.51±11.51	1.78±0.11
	LONG TERM	309.60±7.34	180.29±7.08	524.91±12.52	2.06±0.00
DIET IV	SHORT TERM	452.14±0.08	318.24±6.14	455.84±14.94	2.39±0.02
	LONG TERM	519.96±11.07	369.16±8.45	528.77±10.26	2.77±0.00

Values are means of 4 determination s±SD

Legend: Short term – 4 weeks Long term – 13 weeks
 SGOT – Serum glutamate oxaloacetate transaminase (IU) SGPT - Serum glutamate pyruvate transaminase (IU)
 ALKALINE P^r ASE – Alakaline Phosphatase (μ/L) Creatinine – (mg/d)

SOURCES: Ologunde, M. O., Olaniyan, S. A., Fapojuwo, O. O., Liasu, M. O., and Olunlade, B. A. (2008). Haematological Parameters of Rats Fed On Prolonged Crude Oil Contaminated Cassava Diets. *American-Eurasian Journal of Sustainable Agriculture*. 2 (3) 242 – 248.

EFFECT OF HYDROCARBON CONTAMINANTS ON TISSUE LIPIDS

Polycyclic aromatic hydrocarbons (PAH) are ubiquitous compounds composed by the fusion of several benzene rings (Macubin *et al.*, 1985). They are also natural constituents of crude oil. PAHs accounts for about 20% of total hydrocarbons in crude oil and are the most biologically toxic of all the petroleum compounds. PAH accumulation can have serious implications for human health as certain PAHs are carcinogenic (Uthe *et al.*, 1986).

In the study by Ologunde and Adeyemi (2007), we evaluated the effect of hydrocarbons from crude oil contaminated diets on organ weights and rat histology using animal bioassay procedure. The results presented in the table below showed organs from animals in group III to exhibit the highest percentage of liver lipid while diet IV gave the highest percentage of heart lipid. The significance of this observation has to do with the fact that most of these chemical pollutants are hydrocarbon in nature and apart from being lipid soluble they also resemble plasma free fatty acids. The hydrocarbons being fat soluble materials accumulate in fatty tissue where they bio-concentrate up the food chain. Hydrocarbons have been known to disrupt the lipid bilayer of cell membranes. Liver and the heart are significantly targeted because any effect on these two organs will immediately manifest in various forms of disruptions of the body's metabolic processes.

The long-term effects of some of these toxic hydrocarbons that have escaped food processing operations pose a great problem. Many of the PAHs can be bio-accumulated in organisms such as fish and other terrestrial animals and plants that are ultimately consumed by man. They have extremely long half-lives. This implies that the catastrophic health effects do not manifest immediately.

TABLE 17: BODY WEIGHT AND TISSUE LIPID CONTENT OF RATS FED ON POLLUTED DIETS

	DIET I	DIET II	DIET III	DIET IV
Food Efficiency Ratio	0.30±0.02	0.28±0.01	0.27±0.02	0.26±0.01
Liver Lipid Content (% Liver weight)	5.94±0.21	6.05±0.22	6.48±0.16	6.30±0.13
Heart Lipid Content (% Heart weight)	3.75±0.18	3.79±0.21	4.12±0.21	4.32±0.18
Heart weight (g)	0.63±0.32	0.66±0.12	0.50±0.01	0.63±0.02

Values are means of 4 determinations±SD

SOURCE: Ologunde, M. O. (2005) Crude-Oil contamination of local food sources – A study of Selected locations in the Niger Delta area, Ph.D Thesis, Ladoke Akintola University of Technology, Ogbomoso.

The use of an animal model experiment has long been tried with reliability (Hallberg *et al.*, 1979). There is strong evidence that humans and rats absorb similar percentages of nutrients when nutrient statuses and intakes relative to requirements are similar (Zhang *et al.*, 1989). The biochemical mechanisms of absorption of food nutrients are similar in rats and humans. Thus the results obtained from this exercise are the basis of a reasonable prediction of human response. The work of Georgewell (2002) did confirm our position.

That the PAHs are toxic is not in question. The presence of this PAH has been linked with the development of cancerous cells in aquatic animals (Hinchala, 2000). When PAH levels in the tissue cells were compared, concentration of anthracene in the liver was observed to be the highest.

This value was, however, followed by the level in the kidney (Table 18B). Gross changes in organ weights were also noticed. We observed evidence of stress reaction in the form of an increase in body weight ratio of some organs and loss of weight of some others relative to the weight in the control animals. This observation was in agreement with the work of Chu *et al.* (1992) who reported increase in liver weight of rats after short term treatment with coal co-processing products. The observation of an increase in absolute spleen weight as well as spleen/body weight ratio in the experimental diet (IV) and the high incidence of abnormal spleen morphology found at necropsy indicated that the chemical toxicant in diet IV affected spleen to a greater extent than any other experimental diet. Looms (1968) showed that the weight of certain organ of the body is more constant than body weight. These organs include brain, kidney and liver. Hence we concluded that any shift in weight of these organs is a manifestation of an adverse reaction in the animal. These observations (Table 20A) actually corroborated the findings in Table 20B.

In a similar study by Georgewell (2002) on rats, the author observed that histopathological specimen of the crude-oil treated group revealed multi-organ pathology when compared to the organs of the rats in the control group. These organs exhibited normal cellular architecture. The kidneys showed tubular necrosis and interstitial hemorrhage. The heart tissue showed cardiac muscular congestion. The liver showed edema of hepatic sinusoids. Authors also observed marked elevations of organ-specific enzymes in the rats of experimental diets. These findings by Georgewell (2002) were consistent with our observations.

TABLE 18A: SUMMARY OF HISTOLOGICAL CHANGES IN RATS FED POLLUTANT-CONTAMINATED DIETS

	Short Term (Four weeks) ^a			Long Term (13 weeks) ^b		
	Kidney	Liver	Small intestine	Kidney	Liver	Small intestine
Diet I	0 ^c	0	0	3.0±0.2 ^d	4.0±0.2	4.0±0.2
Diet II	5.0±0.4 ^c	4.0±0.3	6.0±0.4	4.0±0.4	4.0±0.8	3.0±0.8
Diet III	3.0±0.4	3.0±0.5	3.0±0.7	4.0±0.8	5.0±0.7	2.0±0.8
Diet IV	6.0±0.6	6.0±0.8	2.0±0.7	4.0±0.8	4.0±0.8	6.0±0.7

^aSix animals per group

^bFour animals per group

^cNumber of animals with histological changes

^dNumber in brackets denotes severity where 0.1 = very mild, 0.2 = mild, 0.3 = not too moderate
0.4 = moderate, 0.5 = very moderate, 0.6 = severe
0.7 = very severe, 0.8 = extremely severe

SOURCE: Ologunde, M. O. and Adeyemi, I.A. (2007). Evaluation of the Effect of Hydrocarbon from Crude Oil Contaminated Diets on Organ Weight and Rat Histology. *Journal of Applied and Environmental Sciences*. 3 (1) 44-50.

TABLE 18B: OBSERVED CHANGES IN THE INTERNAL ORGANS OF THE ANIMALS

DIET	ORGAN	OBSERVED CHANGES
I	Kidney	Normal cells. Empty tubules and glomeruli
	Liver	Normal prominent vessels, healthy cells and normal circulation, no pooling of blood
	Small intestine	Mild congestion. Normal villi
	Kidney	Mild degenerative changes of proxima; and distal tubules. lower incidence of renal tubular changes
II	Liver	Swelling of individual hepatic cells, picnosis of nuclei and dense chromatin bodies which are indicative of hyperplastic reaction
	Small intestine	Shrunken villi, slight mucosal hypertrophy, oedemation of cells
	Kidney	Edema of glomeruli and tubules. Areas of tubular debris in glomerular space.
III	Liver	Mild central lobular vacuolation. Picnosis of Kupffer cells. Areas of sinusoidal congestion, areas of cloudy swelling.
	Small intestine	Mucosal hypertrophy with shrunken villi. Damaged epithelia surfaces with fragmented nuclei in some areas
	Kidney	Pooling of blood, inflammatory cells and degeneration of distal tubules especially about the descending loop

IV	Liver	Picnosis of Kupffercells. Areas of sinusoidal congestion
	Small intestine	Inflamed mucosal capillary-venous vasodilation

SOURCE:Ologunde, M. O. and Adeyemi, I.A. (2007). Evaluation of the Effect of Hydrocarbon from Crude Oil Contaminated Diets on Organ Weight and Rat Histology. Journal of Applied and Environmental Sciences. 3 (1) 44-50.

Histological observations made in most liver specimens were most conclusive since the liver receives absorbed nutrients including food chemical contaminants from the small intestine. The absorption was through the hepatic portal vein for storage in the liver before distribution to all parts of the body. In the course of this storage, the liver bio-concentrates these contaminants. Where the concentrations of the toxicants exceeded a threshold level, the tissue would be damaged (see slides of histological changes, Plates 7A-7E).

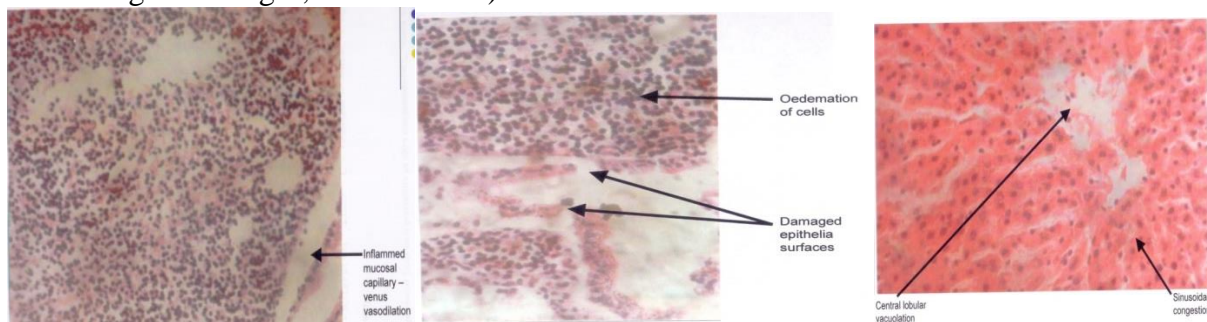


PLATE 7A: INTESTINE 4B (x800) PLATE 7B: INTESTINE 3B (X800) PLATE 7C:LIVER 3D (X800)

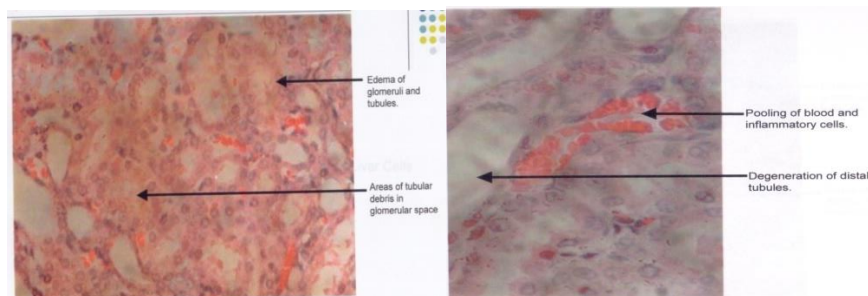


PLATE 7D: KIDNEY 3C (X800)

PLATE 7E: KIDNEY 4C (X800)

Sourcefor 7A- 7E: Ologunde, M. O. and Adeyemi, I.A. (2007). Evaluation of the Effect of Hydrocarbon from Crude Oil Contaminated Diets on Organ Weight and Rat Histology. Journal of Applied and Environmental Sciences. 3 (1) 44-50.

Georgewell (2002) reported that about 362 cancer cases were treated at University of Port Harcourt Teaching Hospital (UPTH) between December 1997 and December 2000. Of these, 186 came from Bayelsa, 154 from Rivers and 22 from Abia, AkwaIbom and Cross River states indigenes who were resident in Port Harcourt. Out of 362 reported cases, carcinomas of the reproductive system were 251, liver 53, gastro intestinal tract (GIT) 40 and others were leukemia and lung cancer 18. Correlation analysis showed that the incidence of cancer in these communities correlated positively with oil exploration and polluting activities. We were of the same opinion.

In a parallel study (Ologunde *et al.*,2007) authors investigated the metal content of processed and unprocessed food ingredients from crude oil processing communities of the Niger Delta using procedures as earlier reported. Our findings were consistent with earlier observations.

Toxicity of a metal in the body depends on a number of factors which includes the bioavailability of the particular metal for uptake, the form of the metal in the feed, the presence of other metals or toxicants, extrinsic physical factors and extrinsic biological factors which affect the physiological condition of an exposed organism. Toxic metal contaminant-nutrient interactions arise primarily from the continuous consumption of contaminated food especially those food items from

the crude oil processing communities of the Niger Delta. Some of these contaminants get into foods naturally through photosynthetic activity of plants and later bio-accumulate.

Any condition, in which chemical contaminant clearance is impaired, such as liver or kidney disease, enhances the possibility of a chemical-nutrient interaction if contaminant levels are not adequately monitored. As a consequence of the above and in view of the dangers these heavy metals pose in nutrition and in the etiology of diseases we decided to investigate the tissue bioavailability in animals that predate on them.

Our findings: We observed that toxic metal accumulations in tissues were directly proportional to feed intake with the small intestine having the highest level of accumulation. This situation is prone to cancer of the intestine in the primary consideration and that of other internal organs like liver, kidney or even the brain especially when prolonged bioaccumulation has occurred over the years.

OUR EFFORTS AT EVALUATING ENVIRONMENTAL CONTAMINATION OF STREET PREPARED FOODS

The pollution of street foods with heavy metals derived from the exhaust fumes of street-plying automobiles is a problem from both hygiene and Eco toxicological points of view. I have always shown concern about wholesomeness of food and more importantly about possible contamination of food items processed and sold by the road side especially in high traffic density areas like busy motor parks, traffic junctions, major roundabouts, etc. I have witnessed situations during which consumers of some street foods developed abdominal cramps or some other signs of discomforts following consumption of such food items. These and similar concerns prompted my interest in conducting a nutritional survey on 'Street prepared foods'.

In several countries especially those participating in environmental monitoring programme, great attention has been given to determining chemical pollutants such as heavy metals in foods sold or processed near industrial centres with a lot of gaseous emissions or sites of heavy automobile exhaust. Because emissions of these pollutants occur near ground level, they are not diluted and dispersed as effectively as pollutants emitted from chimneys. The emissions later settle on street foods and any other available food item that is left uncovered including potable water. Of the many sources of contamination identified, emission from commercial vehicles especially from those using leaded fuel are most dangerous (Ologunde and Abiona, 2005). Cooking water, especially from contaminated sources and industrial gaseous emissions from chimneys (Ewekoro and Sagamu cement works) are other potent sources that may increase the toxic load of heavy metals on these food items.

The health risk of a street food is not only determined by the concentration of various additives or contaminant in the food product, but also by the cumulative daily intake of a certain contaminant or additive through a consumer's life-time. In view of the large segment of the population that patronizes the street food industry (most especially in urban centres) coupled with the potential toxicity of these toxic heavy metals in the body following bioaccumulation, it became necessary to carry out a preliminary evaluation of base line concentration of these metals in street foods towards a better understanding of their roles in street food nutrition.

The toxic metal contents of ten popularly consumed street food items from many traffic flashpoints in Lagos (five locations), Ibadan, Ilorin, Jebba up to Mokwa in Niger state (five states survey). A similar exercise was also carried out in the following towns: Ogbomoso, Osogbo, Ilesa, Ondo, Ore, Benin city, Asaba terminating at Onitsha (another five states). This study was repeated twice within ten years to observe whether results earlier generated were reproducible. The same trend, now even made worse with increase in the number of vehicles on the roads!

Our observations revealed the presence of lead as the most predominant heavy metal (0.68 ± 0.02 ug/g) in roasted plantain in all the areas sampled. A similar trend was observed for other metals especially chromium and cadmium. When the preponderance of these metals was compared with the

levels of the elements in the popular premium motor spirits used by internal combustion engines one was right to conclude that automobile exhausts constituted the major source of these pollutants.

TABLE 19A: CONCENTRATION OF LEAD IN FOOD SAMPLES

			Rice	Beans	Eba& Soup	Amala& Soup	Iyan&Egusi	Jollof Rice	Fried Yam	Fufu& Soup	Roasted Plantain	Akara Ball
A	1	Ojoo, Ibadan	0.25±0.02	0.21±0.02	0.20±0.00	0.06±0.02						
	2	Sango	0.12±0.04	0.28±0.03		0.06±0.02	0.15±0.02			0.21±0.02	0.40±0.02	0.12±0.03
	3	Challenge	0.24±0.02		0.13±0.00	0.15±0.06					0.68±0.12	
B	4	Ojota	0.12±0.00	0.20±0.01	0.14±0.02			0.14±0.03				
	5	Ikeja Market	0.09±0.05	0.10±0.00	0.16±0.01				0.12±0.06		0.26±0.04	
	6	Oba Akran	0.14±0.00	0.11±0.02	0.28±0.04	0.28±0.06		0.10±0.00	0.52±0.00		0.60±0.00	
C	7	Oyingbo	0.09±0.01						0.25±0.01		0.16±0.09	
	8	Obalende	0.16±0.02		0.16±0.01	0.20±0.09						0.22±0.03
	9	Ojuelegba	0.07±0.00	0.07±0.01	0.13±0.06			0.12±0.02	0.21±0.01		0.23±0.02	
D	10	Bolade B/S	0.18±0.01	0.08±0.08	0.18±0.02	0.18±0.03	0.16±0.01		0.18±0.00	0.09±0.02	0.25±0.01	
	11	Oshodi	0.20±0.08	0.09±0.07	0.22±0.03	0.21±0.03	0.11±0.02	0.09±0.03	0.15±0.11	0.09±0.30	0.24±0.01	
	12	Yaba	0.09±0.00	0.20±0.00	0.16±0.00	0.17±0.00					0.23±0.02	
E	13	Victoria Island	0.08±0.02	0.09±0.01	0.12±0.02			0.17±0.00		0.30±0.02		
	14	Ikoyi, Lagos			0.10±0.00					0.40±0.02		
F	15	Cement Works	0.09±0.01	0.16±0.05								0.09±0.04
	16	Shagamu town	0.13±0.08	0.12±0.05	0.10±0.00	0.14±0.00					0.15±0.03	

Values are means of 4 determinations±SD

SOURCE: Ologunde, M. O. and Abiona, O.O. (2005). Toxic and Nutritive Metals as a Function of Traffic Density in South Western Nigeria. Journal of Applied and Environmental Sciences. 1, 14-24.

TABLE 19B: CONCENTRATION OF CADMIUM IN FOOD SAMPLES

			Rice	Beans	Eba& Soup	Amala& Soup	Iyan&Egusi	Jollof Rice	Fried Yam	Fufu& Soup	Roasted Plantain	Akara Ball
A	1	Ojoo, Ibadan	0.20±0.04	1.18±0.04	0.20±0.04	1.21±0.01	0.15±0.02			0.20±0.01	0.30±0.01	
	2	Sango	0.14±0.05			0.17±0.03					0.18±0.09	0.20±0.11
	3	Challenge	0.19±0.02	0.21±0.00	0.30±0.07	0.20±0.02				0.16±0.05	0.14±0.01	
B	4	Ojota	0.16±0.04	0.17±0.01	0.10±0.02	0.39±0.01		0.14±0.06	0.12±0.01		0.17±0.00	
	5	Ikeja Market	0.17±0.01	0.17±0.01	0.06±0.01				0.15±0.01		0.21±0.10	
	6	Oba Akran	0.08±0.02	0.11±0.09	0.18±0.00	0.14±0.08		0.18±0.07	1.15±0.07		1.10±0.00	
C	7	Oyingbo	0.21±0.04	0.12±0.03								
	8	Obalende	0.16±0.02		0.20±0.00	0.16±0.07						0.17±0.10
	9	Ojuelegba	0.16±0.06	0.11±0.04	0.18±0.06			0.17±0.06	0.14±0.07		0.13±0.07	
D	10	Bolade B/S	0.20±0.08	0.16±0.06	0.08±0.01	0.10±0.06	0.13±0.04	0.13±0.02	0.17±0.01	0.15±0.01	0.81±0.03	
	11	Oshodi	0.12±0.01	0.13±0.04	0.12±0.01	0.10±0.00	0.12±0.02	0.15±0.08	0.17±0.01	0.21±0.02	0.18±0.07	
	12	Yaba	0.15±0.01	0.02±0.04	0.21±0.01	0.20±0.04			0.23±0.04		0.19±0.04	
E	13	Victoria Island		0.16±0.03	0.17±0.03			0.10±0.00		0.17±0.00		
	14	Ikoyi, Lagos	0.15±0.05		0.17±0.03					0.16±0.01		
F	15	Cement Works	0.81±0.05	0.10±0.02							1.01±0.20	
	16	Shagamu town	0.14±0.02	0.10±0.00	0.15±0.01	0.13±0.02					1.14±0.23	

Values are means of 4 determinations±SD

SOURCE: Ologunde, M. O. and Abiona, O.O. (2005). Toxic and Nutritive Metals as a Function of Traffic Density in South Western Nigeria. Journal of Applied and Environmental Sciences. 1, 14-24.

At this juncture it must be emphasized that lead, chromium and cadmium are accumulated in human tissues and hence harmful to man's health. The maximum level of lead ($0.68 \pm 0.02 \text{ ug g}^{-1}$) and cadmium ($1.14 \pm 0.23 \text{ ug g}^{-1}$) present in roasted plantain are significantly higher than the percent tolerable weekly intake (PTWI) for this element. In the case of chromium and cadmium, values obtained were equally high especially in locations of high traffic. However, lower values below PTWI for each metal were obtained in areas with reduced volumes of traffic. For metals like zinc and iron, lower values were obtained except in two cases where the fairly high values were traced to the intervention of processing water. These results constitute serious threat for roasted plantain

consumers especially during the season of plenty of this food item. The problems of lead in nutrition are enormous. Lead competes with calcium, inhibiting the release of neurotransmitters and interfering with the regulation of cell metabolism by binding to second messenger calcium receptors. Children are more sensitive to these metals and hence are at greater risk than others. Negative effects on behaviour and intelligence of children are found even at lower levels of exposure than those commonly associated with lead poisoning. Other metals detected at significant concentrations in street foods include cadmium, arsenic, chromium and zinc.

Mr. Vice Chancellor, sir, this study has showed the risks inherent on dependence on street foods as a major source of calorie intake. This situation must not be allowed to continue. This concern will be addressed as part of our recommendations.

OUR EFFORTS AT IDENTIFYING POTABLE WATER FOR DRINKING AND FOOD PROCESSING

POLLUTION OF GROUNDWATER

Globally, at least two billion people depend upon groundwater as the principal source of their drinking water. Recent forecasts suggest that the combined effects of population growth, global warming and land use change will, in the near future, lead to even greater reliance on groundwater for public water supply (Xi *et al.*, 2016).

There is a wide body of data to support the fact that the nation's surface and ground water sources are not clean after all. Oxygen-demanding organic matter has grossly contaminated them, toxic and hazardous substances including heavy metals, pesticides, trihalomethanes and petroleum hydrocarbons are also included.

Arising from the above the quality of potable water sources in the following critical areas were investigated:

- Areas around Gari processing locations. Since this is a major cottage industry which spreads across both rural and urban settings. The operators of these cottage industries require water for cleaning the peeled cassava as well as for drinking and other domestic uses.
- Areas around urban streams especially those streams which are 'environmental sinks' for all kinds of wastes including pesticides, discharges from industries, septic leaks, effluents from agricultural fields, domestically generated wastes and other forms of chemicals.

(a) CONTAMINATION OF UNDERGROUND WATER AQUIFER IN GARI PROCESSING SITES

The extent of percolation of effluents from cassava processing into the underground aquifer in some selected locations in and around Ogbomoso metropolis. During the grating of cassava to produce gari and other by products, the extracellular enzyme linamarase present in cassava gains access to the cyanogenic glycosides linamarin and lotaustralin. The enzyme catalyses the hydrolysis of the substrate to give glucose and cyanohydrins, the latter breaks down rapidly to give HCN and acetone in alkaline solution at ambient temperature. Part of this sinks down by percolation while a greater amount is emptied into the near stream as run off.

One of the major threats to the environment by the *gari* industry is HCN as well as other chemical pollutants that are generated in the gaseous form. These are potent toxicants not only to the *gari* processor but also to the immediate environment. For now, most of the *gari* industries are on a small scale. With the increasing popularity of the new mechanized *gari* factories producing *gari* for local consumption and for export coupled with the extraction of its starch for industrial use, the future will see large *gari* plants and gaseous chemical pollutants will become a major problem. The possibility of expansion of the processing operations is highly imminent. This implies that more

pollution of the underground aquifer will be more. Hence, the need to put in place ahead of this development needful measures to curtail this threat to both the environment and the health of the populace around the processing sites.

Apart from the toxicity of HCN, gaseous HCN when washed down with the rain could result in acid rains (Oke, 1969). During processing and washing, cyanide ion, polycyclic aromatic hydrocarbons and heavy metal contaminants are introduced to the environment by the effluent in the form of hydrocyanic acid which in most cases are bound with PAH and heavy metals (Imevbore *et al*, 1987). If these products are not properly treated, they constitute potent toxicants to the soil, soil organisms and plants. This effect does not come only from the toxicity of the CN – but also from the acidity effect of hydrocyanic acid and the various threats posed by the hydrocarbons and the heavy metals.

The peel is another by-product of *garri* processing which has to be treated properly. The peel not only contains cyanogenic glycosides and free HCN that can be degraded and leached into the soil, it also contains some non-nutritive metals that can interfere with soil electrolyte balance when in excess (Osuntokun *et al*, 1969).

The cyanide content of most samples in Table 20A – 20B, were observed to range between 0.01 ± 0.00 and 0.02 ± 0.01 both for well water samples and the effluent discharge. This fairly constant value could perhaps be due to immediate liberation of HCN and diffusion into the atmosphere. Despite the low value, the observed values were more than the control and significantly higher than the lethal threshold expected in the sample of food materials including water (FAO, 1979).

The role of cyanide in nutrition and its metabolism in human has been well documented (Anosike and Ologunde, 1979; Osuntokun, 1973). Its effect on the respiratory chain via blocking of electron transport chain and consequent loss of energy has been reported by many authors (Osuntokun *et al*, 1969; Oke, 1969). Thus the implication of this high level of cyanide in the environment and its possible impact on the water supply situation is a matter that should be urgently addressed. Cyanide is absorbed into blood where it impairs oxygen utilization via a chemical change that keeps the oxygen from getting into the red blood cells. Long term exposure can lead to convulsion, goiter, ataxic neuropathy, low heartbeat and other signs of depressions. That these effects have not manifested, is not an indication that they are not present. They have probably not reached threshold levels.

The findings which are summarized the table below reveal extreme contamination of well water within a radius nearly 60.0 feet to each processing site. Concentration of cyanide in samples of well water as high as $8.57 \text{ mgCN}/100\text{cm}^3$ of water was observed.





PLATE 8: IMAGES OF CASSAVA PROCESSING SITES (OGBOMOSO AREA) SHOWING EFFLUENT DISCHARGES ON THE GROUND.

SOURCE: Ologunde *et al.*, 2005.

(b) CONTAMINATION OF WELL WATER SOURCES AROUND URBAN RIVERS

Most urban centres in the south west are replete with one or two major streams that traverse the major landscape. In most cases these streams are known to evacuate the run offs that accompany both heavy and light rain falls. In the process, urban/municipal wastes are so removed. In other situations these streams serve as environmental sinks for all forms of wastes generated in the community. Suffice it to say that in some situations most of these water bodies are used for drinking in some locations far away.

For drinking water to be wholesome, it should not present a risk of infection or contain unacceptable concentration of chemical hazardous to health and should be aesthetically acceptable to the consumers. The infection risks associated with drinking water are primarily those posed by faecal pollution and their control depends on being able to assess the risks from any water sources and to apply suitable treatment to eliminate the identified risks.

In view of the role of water in food processing some sources of water especially those in urban areas were selected for study.

The following Rivers were selected for the study:

- Asa River in Ilorin.
- Ora River in Ogbomoso and Odo Oba village.
- Ogbagba River in Osogbo.
- OdoIro River in Ilesa.
- Aiba River in Iwo.
- Ogunpa River in Ibadan.

The indicator pollutants investigated were heavy metals. Only water samples from wells located on the banks of Asa River in Ilorin and Ogunpa River in Ibadan showed significant concentrations of lead, cadmium and iron, in all cases values obtained were above WHO minimum standard for drinking water. The high concentrations for these metals can be attributed to leachates from industrial activities, run-off from near-by agricultural fields, automobile crank case oil discharged directly into near-by streams in the catchment areas. Since these are streams that traverse the urban areas, the possible contribution of wastes generated from the households with its content of diverse constituents of chemical, electronic and metallic components cannot be ruled out. Consequently, the need for effective water treatment becomes highly imperative.



PLATE 9 : DRINKING WATER FROM A POLLUTED/CONTAMINATED SOURCE.
SOURCE : INTERNET PHOTO.

NUTRACEUTICALS: EMERGING AREA OF GOOD NUTRITIONAL HEALTH FOR THE ADULTHOOD

An emerging trend in nutrition and health research is the importance of nutraceuticals in foods.

What are these nutraceuticals?

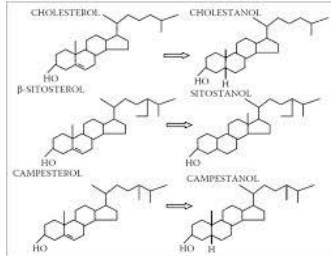
The word nutraceuticals is derived from the words nutrition and pharmaceutical and it refers to foods and food-derived substances with potential health benefits. Therefore, nutraceuticals collectively refer to a wide variety of products including foods, herbs, spices, cholesterol-free foods, fat-free foods beverages, energy drinks, specifically formulated diets, isolated food components, vitamins minerals, trace elements and probiotics.

As part of our efforts in promoting health and wellbeing, we got a grant from TETFUND to determine the nutraceuticals composition of commonly consumed foods in South West Nigeria. The study has quantified the dietary intake of these nutraceuticals and pursue ways to increase the intake levels following the well documented benefits of these nutraceuticals in the prevention and management of several non-communicable diseases. Although many of these nutraceuticals are widely distributed in foods, poor dietary diversity, food processing and preparation procedures and monotony of diets limit their utilization. The phytochemicals possess a variety of bio-active substances: antioxidant and anti-inflammatory that have been implicated in slowing the pathogenesis of chronic disease. These substances have the capacity to promote detoxification, reduce cell proliferation, and/or lower serum LDL-cholesterol. Importantly, these compounds may work in synergy with other important nutritional constituents like vitamins, minerals, mono- and polyunsaturated fatty acids, proteins, and fiber. Phytochemicals are not as widely known as macronutrients, such as protein and carbohydrates, or micronutrients, such as vitamins and minerals. Nonetheless, they may contribute just as much to optimal human health as these other vital nutrients do. More than 1,000 phytochemicals have been discovered, and scientists believe that there may be many still to be found. My interest is to harness the knowledge of food science, technology and engineering to extract these nutraceuticals from the less utilized or neglected food crops where they abundantly occur and promote their incorporation into the commonly consumed foods. This will enhance the intake of these substances without necessitating change in dietary habits of the consumers. Some of these nutraceuticals are further discussed below.

PHYTOSTEROLS

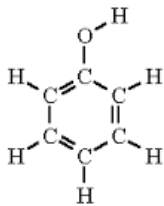
Phytosterols are a group of >200 naturally occurring plant sterols with the capacity to inhibit the absorption of dietary cholesterol and lower serum cholesterol as well as antagonize selected inflammatory pathways. Phytosterols, which are structurally similar to cholesterol, are found in the

fatty fraction of nuts. The primary plant sterols in the Western diet are sitosterol (particularly β -sitosterol), stigmasterol, and campesterol, with estimated average intakes at 150-450 mg/d. Efficacious, short-term doses of phytosterols to reduce LDL-cholesterol are formulated into functional foods to achieve intakes of ~ 2 g/d. The phytosterol content of nuts (in mg/100 g) is: almonds, 187; Brazil nuts, 95; cashews, 138; hazelnuts, 120; macadamias, 198; pecans, 150; pine nuts, 198; pistachios, 280; walnuts, 113. Interestingly, these concentrations are comparable to those found in chocolate and flaxseed at 168 and 210 mg/100 g.



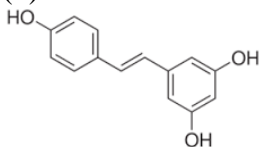
PHENOLS

Plant phenols, including simple phenolic acids, flavonoids, stilbenes, and a variety of other polyphenolic compounds, possess hydroxyl groups conjugated to an aromatic hydrocarbon group. Phenolic compounds are ubiquitous in plant foods with total daily intakes estimated at 500-1000 mg. The reduction in the risk of several chronic diseases associated with the consumption of plant phenols has been attributed to their array of bio-mechanisms, including anti-oxidation, anti-inflammation, carcinogen detoxification, and cholesterol reduction. Pecans, pistachios, and walnuts are rich sources of the phenols.



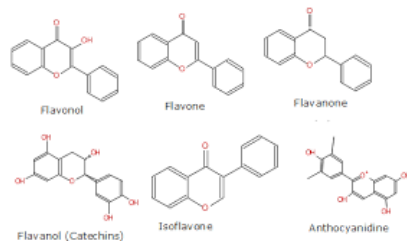
RESVERATROL

Resveratrol is a stilbene and, like many other polyphenols acts in the plant as a phytoalexin. In addition to sharing antioxidant and other bioactivities common to polyphenols, resveratrol appears capable of extending the life span of yeast and mice. In addition to the presence of resveratrol in red wine and the skins of red grapes, it has been found in peanuts and pistachios at 84 and 115 $\mu\text{g}/100$ g (7).



FLAVONOIDS

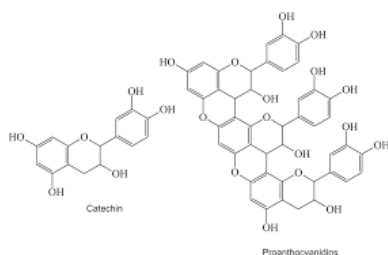
Flavonoids are comprised of six principal classes, anthocyanin, flavanone, flavone, flavanol, flavonol, and isoflavone, and are widely distributed throughout the plant kingdom. Flavonoid intake has been associated with a reduced risk of several chronic diseases with their mechanisms of action variously attributed to their capacity for anti-oxidation, anti-inflammation, anti-proliferation, and modulation of signal transduction pathways. Flavonoids presence has been established in berries (blueberries, raspberries, red, blue and purple berries. Look for local names). Anthocyanidin gives berries their colour and may help protect the body against cancer, neurodegenerative disease and other chronic diseases.



PROANTHOCYANIDINS

The size of proanthocyanidins varies widely in plant foods and is determined by the degree of polymerization. Daily intake of proanthocyanidins has been roughly estimated to range from ~30 to >300 mg/d. Proanthocyanidins have been found in most but not all nuts with concentrations (mg/100 g) in walnuts at 67, peanuts at 16, and cashews at 9. Proanthocyanidins have also been measured in cereals and fruit with sorghum and cocoa containing >1 g/100 g. Some flavanols and proanthocyanidins have been shown to possess chemopreventive activity, promote vascular reactivity, lower platelet aggregation, and reduce urinary tract infections.

The presence of these beneficial phytochemicals/phytosterols has been established in the following fruits and vegetables which are being recommended for consumption:



Citrus

Citrus fruits, including oranges, grapefruit, lemons and limes, contain a type of phytochemical called limonene, which gives a distinct smell to these fruits. Coumarins are phytochemical component of citrus fruits that can act as a natural blood thinner.

Orange-coloured Vegetables

Orange-coloured vegetables such as carrots and sweet potatoes contain a group of phytochemicals called carotenoids. These carotenoids are typically pigmented bright orange or yellow and include the compounds beta-carotene, alpha-carotene, lutein, zeaxanthin and beta-cryptoxanthin. Carotenoids may help maintain eye health and protect the cardiovascular system against attack.

Tomatoes

Tomatoes contain lycopene, a powerful antioxidant phytochemical with a bright red color. Lycopene may have benefits ranging from reducing cancer risk to slowing atherosclerosis. Other phytochemical components in tomatoes that probably work in synergy with lycopene include phytoene and phytofluene.

Soy

Soy contains a class of phytochemicals called isoflavones which may have a protective effect against hormone-dependent cancers such as breast cancer. Some specific isoflavones include genistein and diadzein. Other phytochemicals in soy

include the cholesterol-regulating phytosterols, saponins, the antioxidant phenolic acids and phytates.

Whole Grains

The ferulic acid, caffeic acid and ellagic acid in whole grains have antioxidant properties. These phytochemicals may add to the cancer-fighting properties of fiber and micronutrients also in whole grains.

Red Grapes

Red grapes have a phytochemical called resveratrol that has been implicated in cardiovascular protection. Processing red grapes into other products can affect its phytochemical composition. Resveratrol is at its highest in red wine, but dark red grape juice also contains some of this compound. Red grapes also contain anthocyanidin.

Onions and Garlic

Onions and garlic both have sulfur-containing compounds called sulfoxides, thiosulfates and diithins, which confer their characteristic strong smell and taste. These sulfur-containing phytochemicals act on the cardiovascular and immune systems as well as having antioxidant properties. The flavonoids quercetin and anthocyanin are also present in onions.

Tea

Tea contains catechins, a powerful group of antioxidant phytochemicals. Catechins impart a slightly bitter taste and tawny colour to teas and include the specific compounds epicatechin, epicatechingallate and epigallocatechingallate. Catechins may help lower the risk of cardiovascular disease and stroke, support gastrointestinal health and aid the repair of DNA within cells. Some flavanols and proanthocyanidins have been shown to possess chemopreventive activity, promote vascular reactivity, lower platelet aggregation, and reduce urinary tract infections.

PREVENTION OF CHRONIC DISEASES OF ADULTHOOD

ROLE OF NUTRITION IN THE TREATMENT OF DISEASES

Chronic diseases such as diabetes, cardiovascular disease and cancer are preventable non – communicable conditions associated with risk factors such as poor nutrition and physical activity. The burden of chronic diseases is increasing rapidly worldwide, and the public health approach of primary prevention is considered to be the most cost effective, affordable and sustainable course of action to cope with this epidemic. Reducing population-wide intake of energy – dense, nutrient poor food and drinks will make a big impact throughout society.

The major causes of preventable premature death, illness and disability in adulthood associated with nutrition are;

- Overweight and Obesity
- Coronary heart disease and Stroke
- Hypertension
- Atherosclerosis
- Some forms of cancer
- Type 2 diabetes
- Osteoporosis

- Dental caries
- Gall bladder disease
- Non-cancer disorder of the large bowel
- Nutritional anaemia

The treatment of these diseases requires extremely medical interventions. Future health spending on the management of chronic diseases will account for an increasing proportion of the national health budget due to ageing of the population.

Overweight and obesity

The prevalence of overweight and obesity has increased rapidly and now constitutes an epidemic. Obesity severely reduces health-related quality of life, particularly in terms of pain, functioning capacity and vitality, as well as effects on social functioning and mental of health. Weight gain adversely affects quality of life, while weight loss improves it. In the short term, a moderate weight loss of 5-10% of initial weight in overweight and obese people is associated with substantial health benefits, including improvement in blood pressure, lipid and glucose tolerance.

Coronary Heart Disease and Stroke

Cardiovascular disease (CVD) was the leading cause of burden of disease and was second only to cancer as a cause of premature death. Of the CVD, coronary heart disease (CHD) accounts for nearly 60% of the total mortality and a large proportion of morbidity. The incidence of stroke has become prevalent these days. Stroke is the leading cause of long term disability in adults. Hypertension (high blood pressure) is a major precursor of all these. The risk of stroke and CHD increased continuously with increases in blood pressure. Reduction of blood pressure with medication can reduce the risk of these complications, but may be accompanied by poorly tolerated adverse effects. Several biochemical risk factors for cardiovascular disease such as elevated serum cholesterol are associated with dietary factors. The intake of saturated fatty acids is the key determinants of serum total and LDL cholesterol. The intake of trans fatty acids inversely related to risk of arrhythmia, sudden cardiac death, and thrombosis. The major sources of omega-3 fatty acids are fish and alpha- linolenic acid from peanut oil, linseed oil, soybean oil and green leaves. The intake of trans fatty acids is strongly associated with CHD. The main sources of trans fatty acids are hydrogenated fats and some deep-fried and baked food items.

Diabetes

More than 85% of adults with diabetes suffer from type-2 diabetes, formerly known as adult onset or non-insulin dependent diabetes. Type 1 diabetes (previously known as insulin dependent diabetes) occurs much less frequently and is associated with an absolute deficiency of insulin producing cells. Type 2 diabetes is strongly associated with overweight and obesity, particularly abdominal obesity. Complication of both types of diabetes include blindness, kidney failure, circulating problems which may lead to foot ulceration and gangrene and increased risk of infection, CHD and stroke. Prevention of type 2 diabetes is age-related. Some adults suffer from some form of impaired glucose metabolism, which is highly predictive of later development of type 2 diabetes which is also an important risk factor for cardiovascular diseases.

Cancer

A second most common cause of premature death after CVD is cancer. This may manifest as colorectal, breast, lung and prostate cancers. Cancer is caused by a variety of factors with the most important determinants, being, tobacco, diet, physical activity, alcohol, overweight and obesity, infections, hormone factors and radiation. It has been estimated that around 30% of all cancer are preventable by dietary means making diet second only to tobacco as preventable cause of cancer.

Good nutrition acts as a protective factor against the initiation and promotion of cancers due to exposure to environmental consumption. Increasing average vegetable consumption by just one serving per day, increasing average fruit consumption by one serving per day and decreasing consumption of red and processed meat to less than 2 servings per day will help to ameliorate cancer. There is evidence that inadequate intake of vegetables and fruits is associated with cancer of the mouth, esophagus, lung, stomach and larynx, pancreas, breast and bladder and that inadequate intake of vegetables is associated specifically with colorectal cancer.

Consumption of red meat, particularly processed meat may be associated with colorectal concern. Inadequate physical activity also contributed to colon cancer when rapid growth and greater adult height are associated with breast cancer.

There is convincing evidence that nutrition is a major underlying determinant of a range of chronic diseases and the associated premature death. Programs that promote healthy eating habit, consumption of fruits and vegetables and physical activity, will contribute substantially to improved population health.



PLATE 10: SOURCES OF MICRONUTRIENTS

RECOMMENDATIONS

The rich nutrition profile of less utilized plant food sources such as Amaranths, Pigeon pea and Soybean has been elucidated in this presentation, as part of the efforts to promote dietary diversification in combating hidden hunger and macronutrient malnutrition in the country. The cultivation and increased utilization of these food crops are recommended. This is more important at this time when the prices of foods inhibit food and security of many households following poor economic access and the need for nutrient dense complementary foods is higher.

Following the emerging trends in health research, it is recommended that Nigerian researchers key into the fast emerging area of nutraceuticals. This field is promising in addressing many of the non-communicable diseases at both the preventive and curative phases. It also has the potential to reduce medical tourism that presently pervades many developing nations including Nigeria. Furthermore, this area has the potential to reduce the health care costs as distribution and quantities of these important bioactive substances is enhanced in the food supply. This area may also contribute to economic empowerment and creation of employment. I am once again grateful to TETFUND for the seed fund granted to me for a pilot research in this field.

Furthermore, preventable contamination is a major barrier to healthy food supply in Nigeria especially in the Niger-Delta axis of the nation. It is hereby recommended that policies and action

plan as well as ministries and parastatals with the mandate to control environmental contamination and clean-up of contaminated environment should be strengthened. The harm caused by contamination is far reaching and difficult to reverse; it is therefore necessary to put in place an environment-friendly initiative in approving sites for food processing and production and ensure farmlands and potable water sources are protected from all forms of contamination from industrial wastes especially those arising from the exploitation and exploration of crude oil. I am recommending that Government should set up a nutrition awareness advocacy group that will deal extensively with issues of nutrition education in the Niger Delta area thereby make food supply safer and the food nutrients more bio-available.

Following the large scale of malnutrition in Nigeria, it is hereby recommended that collaboration in researches and intervention activities should be strengthened among the food and health related disciplines. Such collaboration already exists in some Universities in Nigeria and elsewhere, and it is on account of this that I will add my voice to the call for the creation of a Faculty that will cater for such interest in this noble University.

In addition, the school feeding program as presently implemented is a success. More States have indicated intentions to buy into the program. The Federal government recently indicated its intention to take it over and make ninety five billion naira available annually to execute it all over the country. This is a welcome decision. For future sustainability, the policy should be passed into law at the tiers of governance with financial provisions for its yearly implementation made a first line charge in the budget of the Federal budget Government. I am also of the opinion that for the programme to be effective a national Board under a Food Scientist must be put in place as this project is beyond the daily supply of rice, *tuwo*, eggs, meat and the like. Food micronutrients using appropriate food vehicles like drinks, biscuits and other snacks must be served as complementary food items.

There is convincing evidence that nutrition is a major underlying determinant of a range of chronic diseases and the associated premature death especially in adults. Programs that promote healthy eating habits, consumption of fruits and vegetables and physical activity, will contribute substantially to improved population health.

In view of the deplorable situation in any IDP centres, the government should as a matter of serious necessity mandate the Nigerian Institute of food Science and Technology and perhaps other stakeholders to get involved in the management of these centres. The work involved is more than distribution of food stuffs. There is need for homegrown approach which includes supply of locally developed food micronutrients to facilitate the recovery process for the affected members of the camp.

Lastly, it is time for Nigeria to create an environmental pollution-monitoring program for abatement and control that could detect subtle changes in water, raw and processed food sources. These would provide early warning signals of potential gross damage to human health.

Nature of healthy, safe, nutritious foods for the
adulthood in the years to come:
Organic Garden products



Quick Summary

The study of grain amaranth domesticated in Nigeria has generated a lot of data. These data were published in peer-reviewed journals. The sets of data ranged from a consideration of its chemical composition to its use in the development of food items especially those food types relevant to the palate of Nigerians. Such include infant weaning foods, foods for adolescents, adults including geriatric patients. The effectiveness of these in treating cases of micro- and macro- nutrient malnutrition was confirmed, in some cases through animal feeding studies.

Identified gaps in chemical and biochemical analysis were addressed. In this connection, the unresolved issues surrounding the composition of the unsaponifiable fraction were finally resolved consequent on the use of state of-the-art equipment like $^1\text{H-NMR}$ and $^{13}\text{C-NMR}$ among others. Accordingly, critical findings which further reinforced the health and food safety values of the food products were published for the first time in literature.

Furthermore, the research considered the health, nutrition and safety of street foods as produced. Lead concentration was most predominant. The toxic metals identified were highlighted and published in academic journals following which they were made available to health authorities.

The safety and quality of our water supply system was equally given attention in two broad areas due to the inefficiency of the public water supply. These areas are;

- (a) Underground water supply especially from deep wells that fall within twenty (20) meters of major flowing streams and their tributaries. Some of these streams and rivers traverse the entire length and breadth of most towns/cities. They are sometimes referred to as

'*environmental sinks*' in the sense that they harbor a lot of sewage deposits. Pollutants identified were in most cases toxic chemical in nature.

- (b) Other case investigated were areas around cassava processing sites. This became necessary in view of the expansion in cassava processing industry. Indicator pollutants were mostly toxic heavy metals.

In the two cases cited above, abatement procedures were recommended.

The drinking water sources in the crude oil processing areas of the Niger Delta were also reported upon. In addition, the environmental health and food safety value of agricultural food raw materials and processed food items were investigated. Animal bioassay studies carried out with these samples showed that pollutants concentration were in most cases over and above percent tolerable weekly intake (PTWI) for most of these items. In addition, using a combination of advanced chemical and biochemical analysis as well as histopathological examination of specific body organs, it was shown that the safety and wholesomeness of the food items were compromised.

Lastly the use of Soyi-Ogi as food vehicle of iodine fortification and the fortification of spaghetti with vegetable protein sources to improve its food value were carried out in our laboratories in Ogbomoso. Both efforts were successful as the former was highly preferred by individuals with high salt level in their blood.

CONCLUSION

Sir, the three main functions of an academic in the university are: teaching, research and community service. I have taught many generations of students at both the under graduate and post graduate levels. I was involved in research with the outcome published in peer-reviewed journals both locally and off-shore. I was Head of Department of Food Science and engineering for five years during which period the Department represented the University in two Trade Fairs. The university came first at these events. I served on several committees of the Department, Faculty, the University Senate and the University Governing Council. I was the representative of the university congregation on the Governing Council (1992-1994).

Mr. Vice Chancellor, I have contributed to both knowledge ad human capacity development. I have served as external examiner to the University of Agriculture at Makurdi, Modibbo Adama University of Technology, Yola. I have also served as member of the Accreditation team of National Universities Commission. I am a Fellow of the Nigerian Institute of Food Science and Technology.

Between years 2005-2008,I was the acting Director of the University Press and member, Board of University Ventures. It was during my tenure as acting Director that the asset base of the Press improved so much so that we embarked on many developmental projects. From a Cottage Printer with only a small Gestetner machine, the Press has in its domain now a Dark grey Kord 64 and a modern cutting machine among others.

Services during the period I was on Sabbatical leave including part of my accumulated leave include:

1. Foundation Dean, College of Food Science and Technology, Wesley University of Science and Technology, Ondo. I was involved in staff recruitment, curriculum development and such other duties which prepared the ground for the first successful accreditation exercise.
2. Foundation Dean, Faculty of Agriculture and Life Sciences, Federal University Wukari— a Faculty with eight academic Departments. As the first and only Professor that joined the new Federal University, Wukari on Part-time right from take-off in April, 2011, I was involved in

staff recruitment, curriculum development and numerous other duties which prepared the ground for the successful take-off of the University in 2012. My submissions on staff development led to the VC's approval for the recruitment of academic staff in the Graduate Assistant and Assistant Lectureship categories for training towards the Ph.D degree. About **ninety** candidates were employed on merit into this cadre with many of them from the southwest and a significant number being LAUTECH graduates. This exercise paved the way for future human capacity development of the university. As the Dean of the Faculty, I led my colleagues in the faculty to produce the first ever strategic Development Plan that was submitted to the National Universities Commission in 2013.

3. In 2013, having observed the low food nutrient intake in the population in my immediate community, I set up **Michael Olufisayo Ologunde Foundation for Food micronutrient intervention in endemic populations**. The foundation is involved in nutrition education especially in the rural areas where it also distributes locally produced and imported food supplements free-of-charge. Distributions of more than 2000 packets of food supplements free of charge have been made till date. This to me is in a way of giving back to the society what the society has invested in me. This exercise is work in progress. It is the plan of the Board of this Foundation that this exercise will cover the entire states in the southwest in the near future.
4. In a move to bridge the gap created by non-availability of text-books, I established the Food Science Lecture Note Series which attracted other contributors later on. As of today there are many titles covering different aspects of the discipline. Though these titles may not be the end-all, they seek to provide a good template for the development of highly inquisitive minds into potential Nobel Laureates.
5. My services to the community also included serving on the boards of many religious bodies, in most cases either as chairman of Education committees, other decision making bodies or the Youth Work Board. At different times I served (or still serving) on the Boards of the following Anglican Dioceses: Jebba, Jalingo, Oke Osun and Osun.

GRATITUDE

I wish to express with reference my utmost gratitude to God. HE from all goodness flows, for everything I am today and for everything I will be tomorrow, to him be all the glory, honour, adoration, for without him, I am nothing.

My father has been my greatest motivator, my mentor, encourager, and supporter. I want to appreciate him and thank him for his love, understanding, and the personal sacrifices he made to see me to where I am today. The education of his three children and even his grandchildren was of uppermost consideration to him. He laboured hard to ensure we have good education. Papa, on behalf of your children, grand and great grandchildren I say thank you very much for the great sacrifices you put in place to make us what we are today even **at great cost to your own personal pleasure**. I cannot but appreciate my late mother for her personal interest in me and would always remind me at every opportunity to be studious. She scarcely allowed me time for maximum rest. Though she did not have the benefit of western education but you could see the interest she had in education. Mama, I thank you post humously. I wish you were around today. May your dear soul continue to rest in perfect peace, amen. You did not labour in vain. I equally appreciate the contributions of my elder brother, Chief Funso Ologunde. During the usual home lesson exercise on one of those holidays in 1969, he asked me a simple question in my best subject area, Chemistry. I could not answer correctly. I was completely deflated. He literarily forced me to go back to my text

book to obtain the solution. This was the turning point in my academic career. Since then, I learnt to read directly from text books. I appreciate this intervention in my academic life. This culture I carried to the University. To my dear wife, Dr. (Mrs) O.A. Ologunde, an Associate Professor at OAU, Ile-Ife, I thank you for the support all these years. Our children and grandchildren, I say a big thank you. I appreciate you all for your understanding, patience and sacrifices. To my in-laws, I appreciate you for all you have done for me ever since our paths crossed each other.

At this juncture, I must place on very good record the academic contributions of my mentors. First on the list is Prof Oladapo A. Afolabi. He provided me with the platform on which I stand today. I knew him through two sources: first when he came to Nsukka in 1977 for a conference hosted by the Department of Biochemistry. I was an undergraduate student in the penultimate class. He made a brilliant presentation on the chemiosmotic coupling hypothesis of oxidative phosphorylation in the *Firefly*. He and a senior colleague discussed this topic to the admiration of everybody present. I was impressed with his brilliancy. It was because of him that I decided to do higher studies at UNIFE (now OAU). I am very grateful sir. Prof provided me with the connection to Prof O. L. Oke, my father in this profession. Prof Oke deserves every bit of gratitude I can today. I remain forever grateful to you sir for the kind attention and mentorship you have given me all these years. Sir, you recruited me into this profession in 1990 at the inception of this University. It was on your USAID funded grant that you trained me as a researcher. It was also on account of your sponsorship that I was at Cambridge for advanced training in chemical instrumentation. These opportunities made a difference to my academic life, the outcome of which we are witnessing today. Sir, as you age gracefully, my prayer is that your strength and good health will continue to be renewed in Jesus name. God almighty will bless and keep you and continuously make his face to shine upon you, your children and grandchildren, amen. My inestimable gratitude also goes to Dr. Bob Shepard, Howard University, USA. Dr. Shepard accommodated me in his laboratory for twenty months supervising my research works on the Howard University/Obafemi Awolowo University Grain Amaranth Research Project. You made me a part of your family during this period. That friendship stands till today. I owe a lot of gratitude to you sir. The several peer-reviewed academic papers that emerged from the work facilitated my upward movement and remains till today the high point of my commitment to research.

At this juncture, I will like to put on record and on behalf of my colleagues in the Department our special appreciation to the Vice Chancellor and through you sir to the University Management for the steadfast support enjoyed over the years especially during the period of my headship of the Department. Without this support most of the achievements recorded in this lecture would not have been possible. We are grateful sir.

I also want to specially appreciate all our past Vice Chancellors who have made immense contributions to the growth of this institution. Your labours have not been in vein. Whenever the history of this institution is written your names will be engraved in gold. I had the singular privilege of working closely with you during your period of service in this university. Prof O.L.Oke, *FAS, MON*, Late Prof. A. M. Salau, *FNIP*, Late Prof. T.I. Raji; Prof. B.B. Adeleke, *FCIChem* and Prof. M L Nasser. I learnt a lot from you and from your administration. The lessons learnt have formed the bedrock of my administrative experience. Your stars will continue to shine, amen. God says it is not over with you yet. We will have cause to rejoice with you soon. I am very grateful to you sirs.

I must not fail to acknowledge with utmost gratitude the enormous support and mentorship also received from Prof. Diran Famurewa, the pioneer Vice Chancellor of Kings University, Ode Omu, Nigeria. You are a brother and a mentor. You provided me with the academic leadership and mentorship at a most critical moment of my academic career. May God continue to bless you and prosper your ways, amen. My distinguished teacher and brother, Professor, I. A. Adeyemi, you supervised the Ph.D work and invariably a substantial part of this presentation. You contributed a lot into making today possible. I owe you a lot of gratitude for the successful completion of the Ph.D thesis. My distinguished senior colleague, Prof C. O. Aworh, I appreciate your offer of assistance to read through the manuscript at very short notice and for those very helpful comments. Thank you sir. I must not fail to acknowledge the helpful and indefatigable assistance provided by Dr. Oluwaseun Ariyo. Your support and contributions to this work is outstanding. You gave out your best to ensure that this piece is properly and neatly presented. You did all the computer graphics without a sign of discomfort on your face. I recall many days we sat together from dusk to dawn sweating to get this piece ready. Please accept my sincere gratitude. At your hour of need you will never be alone. Bayonle Latinwo, you came in at the right time when I needed your services as a word processor. You filled the vacuum created by the absence from home of some of my children. Thank you very much for this. When I had a ‘hiccup’ on this journey, it was Professor O. Akinyemiju that gave me words of hope and encouragement that rekindled my interest. I am very grateful to you sir. I must not fail to appreciate all my friends, colleagues in the Department, Faculty and the entire university; I thank you all very much. Names are too numerous to mention. God knows you all and He will repay your labour of love and affection, amen. You contributed into making me what I am today. Engr. Prof Adebiyi, the current Dean of the Faculty and Dr. M. O. Oke, my HOD, and in deed all members of the Faculty, I thank you for your sacrifices. I appreciate you all for putting in everything to ensure the success of this lecture. To all my students (Undergraduate and Post Graduate), past and present, I thank you.

I acknowledge with sincere gratitude all my teachers from primary school through my university education for turning me from nothing to something, for all your commitment to making me what I am today, I remain eternally grateful to you all. Of particular note was Papa, the late Venerable (Chief) J. L. Omigbodun, my God father at baptism, my Papa in many ways and my Principal at Osogbo Grammar School, Osogbo. Papa used the personal life example of Booker T. Washington as recorded in his book: *‘UP FROM SLAVERY’*, to teach us so much about diligence, good morals, hard work, the dignity of Labour and the rewards that accompany these throughout life. That training still registers in us till today. I benefitted much from the training. Papa, may your soul continue to rest in perfect peace, amen.

I have saved the best for the concluding segment of my appreciation. Let me wholeheartedly and most sincerely thank the Vice Chancellor, Prof Adeniyi S. Gbadegesin for giving me this opportunity to stand before this august gathering to deliver my inaugural lecture. Sir, I appreciate you greatly for this opportunity and for providing the enabling environment for research to thrive in this university. Not only this, you have equally shown that you are an outstanding and effective manager of men, material and resources. I remain grateful. The Registrar, Rev J. A. Agboola, other Principal Officers, Provost, Deans and Heads of Departments, I say thank you for all your support over the years.

Finally, I appreciate with profound thanks everybody present here today for giving me your precious time to come down to Ogbomoso and listen to my talk. In the name of the Most High God, I wish you all journey mercies back to your various destinations, amen.

I am most grateful. May God bless you all.

Professor Michael Olufisayo Ologunde, *FNIFST*

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