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NEW OLD FOODS

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STEVE R. A. ADEWUSI
Professor of CHEMISTRY

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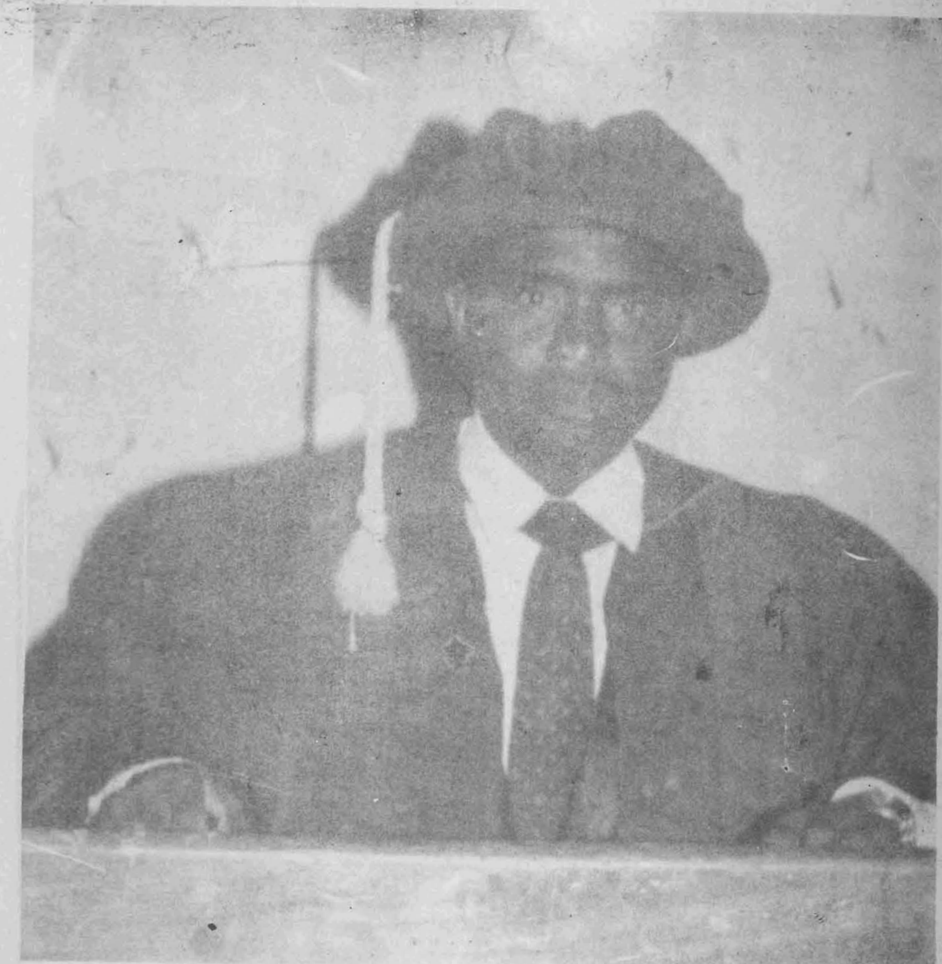

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An Inaugural Lecture Delivered at Oduduwa Hall
Obafemi Awolowo University, Ile-Ife, Nigeria
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IN THE BEGINNING

Preamble

I was a big eater as a baby so said my mother so often that I wondered from my infancy what appeal food held out for me. My interest in good food continued as a young boy and became the most important thing to me as a young man. Now that I am a mature man, food has become my greatest hobby. This is obvious by what I do.

When I was in the secondary school, my parents forbade me to eat cassava products, as it was not good for my eyes. As I was ruminating on this stern order, another bombshell was produced by an eminent scholar. Professor Olumbe Bassir announced at a public lecture that cassava alone is not nutritious and that subsistence on cassava could result in some dreadful diseases. I loved drinking gari for lunch especially with dodo or just the dry gari mixed with sugar, whao, such a lovely taste! So, what were the eminent scientists telling me? What does nutritious mean? Am I interested in food or nutrition? Should I stop eating one of my best foods? You can see how this interest in food has spurred me into Biochemistry as my first and second (M.Phil) degrees and finally Food Chemistry/Toxicology for my Ph.D. I am therefore happy to stand before you today, soon after I became an academic grandfather, to deliver my inaugural lecture titled NEW OLD FOODS.

WHAT IS FOOD?

I do not need to define food for this distinguished audience. Man requires 5 constituents of food for good growth and good health. These are Protein, Carbohydrate, Fat, Mineral and Vitamin - the building blocks of which are provided by the process known as photosynthesis. To understand the importance of this process, I need to take you down the memory lane.

IN THE VERY BEGINNING:

Yoruba mythology acknowledges the creation of the world and light (imole - sun in the day and the moon at night) in the first chapters of Ifa - Oyeku meji Chapters 2 & 3 and Eji Ogbe Chapter 4, Verses 1 - 12. The Holy Bible in the book of Genesis describes creation of heaven and earth and everything else in six days. Of particular interest to us in this treatise is Genesis Chapter 1, Verse 3; "And God said, let there be light and there was light" and so the Lord God, the Omnipotent in His wisdom created light and thus energy on the very first day of creation. On the second day according to Genesis, Chapter 1, verse 11 "and God said, let the earth bring forth grass, the herb yielding seed, and the fruit tree yielding fruits after his kind, whose seed is in itself, upon the earth: and it was so". The importance of light is apparent from the sequence of creation for without light there can be no food and thus no life. The process of photosynthesis, which is essentially the oxidation of water to oxygen and the concomitant reduction of carbon dioxide to carbohydrate, involves the harvest of light energy from 400 to 700 nm wave length band.

SELECTION OF PLANT FOODS BY THE PREHISTORIC MAN.

Modern humans, Homo sapiens sapiens, appeared over much of the Old World about 40,000 to 50,000 years ago (Vasey, 1992). Their predecessors including Homo erectus were hunters and food collectors and their mode of existence was extremely nomadic in search of game. If the prehistoric man was a gatherer of plant foods, this would presuppose a foreknowledge of the seeds and fruits being collected. Between the period of man's appearance on earth and the domestication of crop plants, a period of about 35,000 years or more, how was the Homo sp. selecting his plant foods? Since there is no record of this period, all we can do is speculate and infer from customs that survive. Trial-and-error process has always been a form of pharmacological

experimentation (DerMarderosian, 1993). Man sticks to the tried-and-tested foods during the periods of plenty but during famine or drought, hitherto untried plant foods would be collected, cooked and eaten. If it was safe, it would then become part of the staple diet but if not, the plant would become a "taboo".

Experimentation and Observation: In many instances, the prehistoric man experimented with a new plant food by presenting such to animals and watching from a distance if such food would be eaten eagerly by the animals. This type of crude experimentation is still carried out till today. For instance, some mushrooms look very much alike and if in doubt, part of a new harvest is thrown out to chicken, if the chicken peck the mushroom eagerly, it is safe to be eaten but if ignored entirely, then the mushroom is poisonous and should be discarded. In line with this, was the careful observation by the prehistoric man, of what roots, leaves, seeds and fruits were eaten by animals and which were avoided. For instance, it has been observed in Australia, that wallabies (young kangaroos) would always pick out and eat roots of low cyanide cassava in a farm where both low and high cyanide cassava cultivars have been planted randomly.

THE ORIGIN OF AGRICULTURE: The definitive sign of prehistoric agriculture was morphological change indicative of domestication following a period of evolution of plants and animals under human management. There are many theories about the origin of agriculture but we shall only review a few because of time constraint.

DIFFUSION theory refers to the flow of agricultural practices, ideas or germplasms from one place to another and generally assigns the location of origin to one or two places preferably one in the Old and the other in the New World.

POPULATION PRESSURE AND FOOD CRISIS IN PREHISTORY: This theory suggests that rapid population growth with minimal movement within the population at the time of agricultural inception coupled with food crisis was the factor responsible for the domestication of plants and animals.

ENVIRONMENTAL CHANGE: The origin of agriculture coincided with the late Pleistocene-early Holocene transition period (12,000-15,000 years ago) and with environmental changes. The changes included the rise in temperature leading to the melting of ice sheets in the north and a concomitant rise in sea level. This probably produced a plethora of local changes that had similar effects on food collecting populations. For instance, the dry spell of the early Holocene period may have forced the prehistoric Tehuacan population of Mexico to agriculture. The shrinking land areas in Southeast Asia where about half the landmass was submerged by the rising sea level could have forced the prehistoric population therein to the domestication of plants and animals.

COEVOLUTION - MIDDENS AND THE GARDEN OF THE GODS: This theory states that domestication is the product of slow and largely involuntary social evolution associated with biologically evolving plants and animals. One version of this theory is the "dump-heap" or midden's scenario. This stipulates that middens, where waste products were discarded, became the unintended gardens as people discarded propagating parts and organic wastes that would improve the soil. This version excludes any voluntaristic role for humans at the early stages but selection would be gradually exercised through a cycle of harvest from the garden and the return of propagating parts. The second version of the theory involved religion, which is as old as man himself. Archeological remains of religious materials (figurines of gods and goddesses) indicated that birth, death and food were of

fundamental importance to the prehistoric man. Animals, though killed for food were nevertheless considered akin to humans while the seasonal cycles of the death and rebirth of vegetation were thought to be related to the human life cycle. As a result, the early man tended to offer propitiation to the spirit of the animals killed and the plants harvested for food to ensure future plentiful harvest. It is therefore postulated that the first seed planting was a magicoreligious act to appease the gods. The "first fruits" or "last sheaves" were planted in the "bowel of the earth to appease the Gods to ensure reproduction and a future bumper harvest". These seed offerings were scattered or buried in special fields, which thus became the garden of the gods. Such might be the Garden of Eden in the Holy Bible. This speculation / theory may also account for the major morphological changes in plants as a result of domestication. The early man offered the best seeds or those with unusual characteristics to the Gods with the result that the garden of the gods would have the best and the most exotic fruits and seeds, again like the Garden of Eden? The domestication of animals could also be explained at least in part by this speculation/ theory. There is no evidence of the dog (the first animal to be domesticated) being used as a sacrifice in prehistoric times though they were certainly used for food. However it is possible that goats, sheep and subsequently cattle have been domesticated to make sacrificial animals available. The other side of the coin is that wild animals meant for sacrifice were captured alive and sacrificed at the appropriate time, which would be the first step in domestication. The second short step would be the herding of young animals whose mother had been killed; these young animals may then be nursed by the women to become pets and guarded by dogs already domesticated.

The origin of agriculture will probably require a multivariate explanation combining some of these theories. However the result of domestication is the selection of a few crops out of several thousands for cultivation. Many germplasms still exist wild and provide food for the local inhabitants while the majority has been lost forever. Indeed of the over, 200,000 species of known flowering plants, only three thousand or so have been used to any extent as food by man. Of these, about 200 have been more or less domesticated and only a few dozen are the primary foods that stand between mankind and starvation.

CROPS AND ANIMALS AS FOOD.

Man could find suitable foods almost everywhere (being omnivorous) however a particular human community selects certain plants and animals for consumption. In reality, there are probably less than a - dozen staples between each region of the world and starvation. For instance, rice is the main staple to millions in the South East Asia (China, Japan, Korea etc) as potato is to Europe and beans in Latin America, while wheat has become as close to the universal staple as any food crop. Are these old foods since most of them were amongst the first set of crops to be domesticated? The answer is no as illustrated by the following:

1. CEREALS:

Wheat and barley were the first two cultivated plants some 10,000 -12,000 years BC originating from Africa, specifically in Egypt where it was cultivated at the river valleys at high tide. Einkorn wheat (Triticum monococcum) - a diploid species with 14 chromosomes - was the first planted wheat and still grows wild and/or cultivated as a relic crop in Turkey, Caucasia and parts of Europe till today. This is followed by the tetraploid with 28 chromosomes - the Emmer or macaroni wheat. Emmer wheat was found to be a cross between einkorn and an unidentified goat grass, which is probably extinct by now. The hybrid has a better yield and better characteristics. The latest in the evolution is the hexaploid appearing the 5th millenium BC in

archeological sites. It is another cross between the tetraploid and another goat grass believed to be Aegilops squarrosa. The chromosome from this last goat grass makes the new hybrid better adapted to extreme environments than the other wheat species and varieties. Triticum aestivum, the common bread wheat is the most important variety of the hexaploid species and accounts for 90 % of cultivated wheat worldwide. It is interesting to know that wheat is harvested every month of the year somewhere around the world. Plant breeders, through conscious selection and artificial hybridization have produced about a thousand different varieties of bread wheat in the 20th century alone. Some are designed for agronomic considerations and others for resistance to diseases, adaptation to climate and unique processing requirements. Attempts have been made to develop the hybrid between wheat and rye known as Triticosecale into a crop plant. This hybrid has higher lysine content than wheat though not as suitable for bread making. It is therefore obvious that wheat has undergone enormous transformation from the domesticated plant to what it is today - a new food.

Rice, Maize and Sorghum: Wheat and barley formed the basis for early civilization in Africa and the Near East but rice allowed the development of high cultures in the South-East Asia; Maize accounted for the evolution of the great cultures of the Americas while sorghum and millet sustained the evolving culture of Africa then and now.

Rice, regarded as a sacred plant in much of Asia, belongs to the genus Oryza of which twenty species have been found in the humid tropics. One species, Oryza glaberrima, was domesticated in West Africa and still grows wild in this country especially in Niger State where it hybridizes occasionally with cultivated rice. Another wild ancestral species is Oryza rufipogon, which was domesticated in China and Southeast Asia to give the present day Oryza sativa, which virtually furnishes all the rice of the world today. There are several thousand varieties of Oryza sativa but divided into three main subspecies: the japonica types grown in both Taiwan and Japan, have short grains and are sticky when cooked but are higher yielding. The indica types have long grains and are drier when cooked. People all over the world (except Africa) usually prefer their local staples (whether sticky short grained or long and dry) and are reluctant to change. The research effort of the International Rice Research Institute (IRRI) in the Philippines has resulted in the development of so many customized varieties of rice that would make the early rice-eating mankind turn with envy in his grave. Wild rice, Zizania palustris, a delicacy among the grains is not related to Oryza but is an example of a wild food plant that have been brought into cultivation in the last 20 years in North America.

Maize is referred to as "the gift of the gods" in parts of Mexico and other Latin American countries. Maize (Zea mays) has its origin in Mexico around 5000 BC from a plant called teosinte (Zea mexicana) a coarse annual / perennial wild grass. Maize went from Mexico to Peru, South America around 3,000 BC and later reached what is today the United States of America. It even crossed the sea into Europe in the 16th century AD where it enjoyed a less than rousing success. Conscious selection of maize by ancient plant breeders led to a large variety of the plant in terms of seed size, shape and colour. The outstanding success of the hybrid maize is a testimony to the modern plant breeders and the arrival of a new maize as food. Modern maize such as the opaque-2 mutant with significantly higher lysine and tryptophan content than other types have been created by the Intentional Maize and Wheat Improvement Centre in Mexico.

Sorghum: This plant is supposed to have been domesticated in Africa specifically in the Savannah zone of eastern Africa, north of the equator. The sorghum plant thrives in semi-arid regions that will not support

the growth of other major cereals. A lot of research has gone into the improvement of this plant crop to improve seed yield, color and increase its suitability for the brewing industry.
We have thus seen that most of the crop plants now in existence have been re-engineered by nature and plant breeders through conscious selection, hybridization and artificial crossing to give better yield and hence "new" foods. The impact of biotechnology on the crop plants is making engineering and reengineering of these crops easier such that the plants can produce designer-foods.

REQUIREMENT FOR FOOD

In addition to the provision of basic nutrients, food can also be regarded as medicine. Diseases such as diabetes, phenylketonuria, galactosemia and gout are often managed and controlled by diet and exercise alone. Certain food substances can lower or elevate insulin, "switch-off" enzymes like proteases which "turn on" cancer cells, boost body immunity to diseases and contain antioxidants and chemical scavengers. Others are capable of neutralising the damaging effects of other foods and environmental toxins, (Table 1 shows examples of foods with reported Medical properties). Indeed, the era of "wholistic" medicine in which diet therapy could play a prominent role is here with us! There, was even a school of thought that suggested that most plant foods in use today started as drugs and were domesticated for that purpose.

AND NOW

Let us turn our attention to some old foods that still provide nutrients and fantastic complements to the new staple foods.

THE LUXURY FOOD: Mr. Vice - Chancellor, Sir, and In 1991/92, there was a big inscription in the students' cafeteria of the Australian National University, Canberra that said "FOOD IS EXPENSIVE".

FOOD in this context was defined as flesh/meat dishes alone. Vegetables and grains were mere supplements. In Africa, we hardly get food to eat, so very early in my academic career; I decided to do research in areas that would benefit the most people. During the 1979 elections, one of the presidential candidates promised the electorate that stockfish would be banned because it was not nutritious! This served as an impetus to carry out some research on the luxury food. Our findings published in 1981 (Adewusi *et al.*, 1981) showed that stock fish is indeed nutritious, being high in protein, in particular the amino acids - methionine and lysine while trotters (Ponmo) though high in protein also, failed to support growth or even maintain the status quo of the experimental rats. (PER -3.1 compared to casein's standard PER of 2.5, stockfish 3.0 and big eye fish 3.1).

Table 1: Some Foods with their Reported Medical Properties

	Food	Constituents	Purported Medical Pro
1.	Apple	Pectin, caffeic acid	Lowers cholesterol, blood pre antimicrobial, antidiarrheal p Possible protectant against ca
2.	Banana and plantain	Fiber in unripe plantain, pectin	Prevents and heals ulcers, he blood cholesterol. Stimulates proliferation of ce stomach lining and release of mucous.
3	Broccoli	Indoles, glucosinolates, dithiolthiones, carotenoids	Lowers risk of cancer
4.	Cabbage	Chlorophyll, dithiolthiones, flavonoids, indoles, isothiocyanates, phenolic, caffeic & ferulic acid; vitamins C and E, "growth factor" mucin-like substances	Lowers risk of colonic cancer helps prevent and heal ulcers immune system, kills microb classed as desmutagen (cance antagonist)
5.	Chili Pepper	Capsaicin, vitamin C	Increases mucous secretion in as expectorant, alleviates chr bronchitis and emphysema, decongestant, diminishes clot (fibrinolytic), topically effecti analgesic used in 'cluster" he induces secretion of endorphi
6.	Spices, e.g. cumin, cinnamon, ginger, mustard	Various active principles	Reduced cholesterol levels in
7.	Fenugreek	Various active principles, fiber	Helps control sugar levels in
8.	Garlic	S-allylcysteine-S-oxide, S-methyl- & S-N-propyl - L-cysteine-S-oxide	Antimicrobial, Reduces high pressure. Cardiovascular diseases, canc
9	Onion	S-(prop-l-enyl) – L-cysteine-	

Source: Chavez 2001; DerMarderosian, 1993; Morbidoni et al 2001; Virtanen, 1962.

ALL FLESH IS GRASS. ISAIAH 40 V 6-7

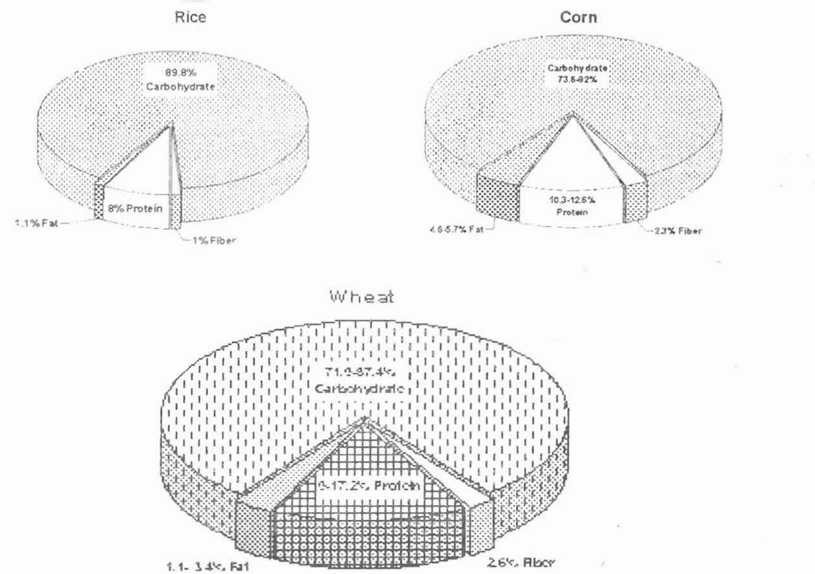
The grasses are the foremost providers of food and beverages for relaxation. The grasses were as seen earlier, among the first set of plants domesticated by man. Let me crave the indulgence of the Vice-Chancellor to start off with a pseudo-cereal of some importance.

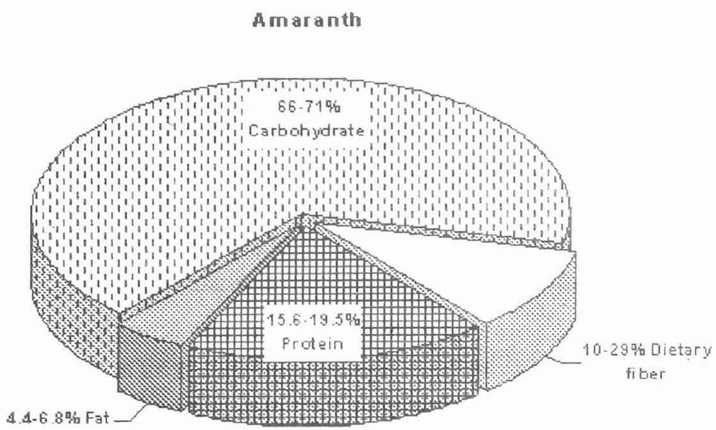
Amaranthus: Amaranths are one of the oldest food crops in Central America where it originated dating back to 7000 BC (Feine et al., 1979) and became one of the most important staples in Mexico at the time of the Spanish conquest. The Amaranth is one of the rare plants whose leaves are edible while the seeds are also used as cereals. Amaranth has received increased scientific attention in recent years as one of the "bypassed" crops having the potential for broadening man's food base.

Amaranth Research in Nigeria: Studies on plant food sources started with Professor Oke in the mid-60s (Oke. 1966, 1975) culminating in his pioneering work on leaf protein concentrates in the 1970s. Work on amaranth grain in Nigeria started with the investigation of the nutritive value of these cereal-like grains (Afolabi et al., 1981) closely followed by another article on the nutritive value of amaranth seeds (Osuntogun and Oke 1983). Professor Oke with Dr Ologunde pioneered the major research effort on agronomical and chemical studies of high-yielding lines of grain amaranth (Ologunde et al., 1992). The study reported that the average yield of amaranth grain (2,976 kg/ha) was comparable to those of maize (3,180 kg/ha) and wheat (2,279 kg/ha). The study further demonstrated that exotic grain amaranths grown under West African agronomic conditions have a

high protein content with substantial levels of lysine and the sulfur-containing amino acids. Crude fat was average with linoleic, oleic and palmitic acids as the major fatty acids. It was further shown that the dietary fiber content was high but tannin was low. The proximate composition of amaranth grain grown in Nigeria is shown in Figure 1 compared to other conventional sources of carbohydrate. The high phytate content however did not affect protein and mineral utilization. All these attributes make the grain amaranth an important alternative grain crop to meet Nigeria's future food requirements.

Figure 1: Proximate Composition of Amaranth grain, Wheat, Corn and Rice





Source: Ologunde, Akinyemiju, ADEWUSI *et al.* (1992)

Vegetable amaranth: Amaranth is more widely used as a potherb and has been found to be the most widely eaten vegetable in South - West Nigeria (Awoyinka et al., 1995). Our study showed that amaranthus vegetable is more succulent than young cassava leaves but contains less crude protein while having the same level of crude fat. Iron, calcium and dietary fiber content as well as in vitro digestibility were higher in amaranthus compared to the cassava leaves.

Now, let us now turn our attention to the actual cereals:

ACHA: (Digitaria exilis Stapf) also commonly called fonio, fundi, petit mil and hungry rice, is an annual grass indigenous to West Africa with about 300,000 ha cultivated between latitude 8o and 14o North of the equator (Jideani and Akingbala, 1993). There is a close relation of acha known as "Iburu" also called black fonio - (Digitaria iburua

Stapf) producing edible seeds almost indistinguishable from acha. Acha as well as iburu plants grow to about 45 cm high with tiny long ears and produce about 700 kg grain per hectare. The major attributes of acha include its ability to grow on poor, sandy soils and the fact that acha contains an exceptionally high level of sulfur containing amino acids - methionine and cysteine. Acha could therefore be an ideal complement for legumes (deficient in sulfur amino acids) and cassava which needs labile sulfur for the detoxification of its cyanide potential.

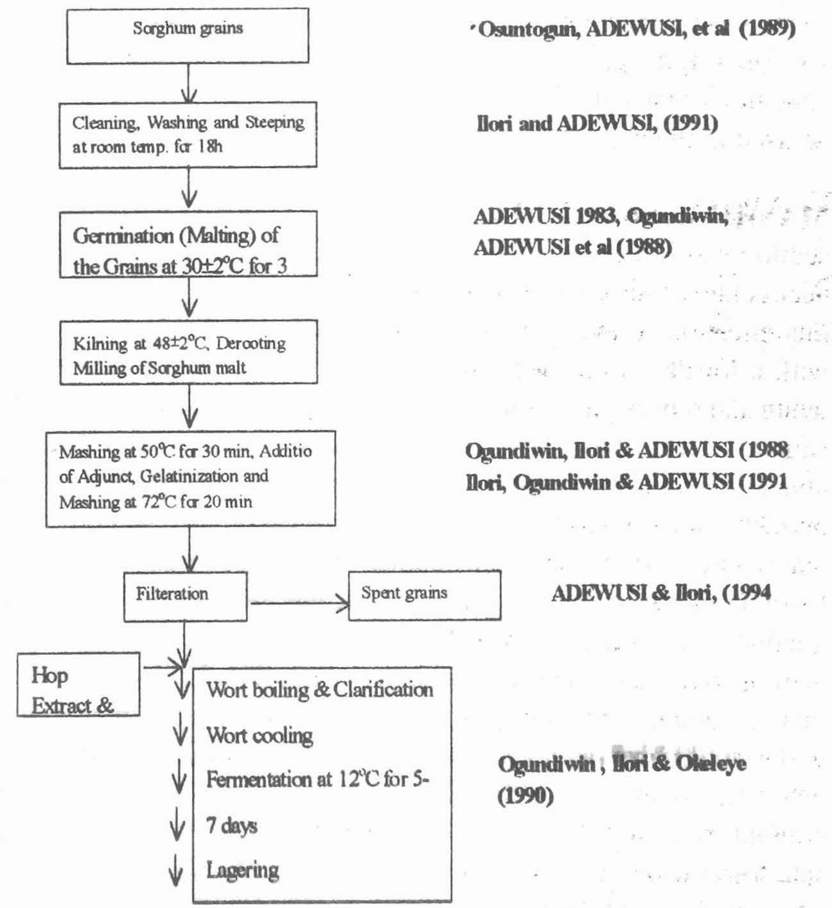
THE STAPLE GRAINS - SORGHUM AND MAIZE: These staples are used in many forms in Nigeria but the most important is ogi - fermented cereal porridge, which is a popular weaning, breakfast and convalescent food. Ogi is made from red or white sorghum as well as yellow and white maize. The general belief however is that ogi from the red variety of sorghum is the most nutritious of all ogi products in spite of its high tannin and phytate content. My group investigated the effect of fermentation and ogi production on the level of anti-nutritional components of grains, the nutritional value of the different varieties of grain and the comparative chemical and nutritional analyses in an attempt to develop an inexpensive weaning diet. Our results (Adewusi et al., 1991) showed that the yield of ogi was highest in white maize and lowest in white sorghum. Cost estimation in 1986 showed the lowest cost again for white maize compared to both white and red varieties of sorghum. Crude protein was highest in ogi from yellow maize and least in red sorghum. Production of ogi reduced tannin and phytate content of the grains by 64-100 % thus improving the nutritional quality of the products. Our bioassay however showed that ogi from red sorghum was better than that from white sorghum but inferior to ogi produced from white and yellow maize. The ogi from white sorghum had a low in vitro starch digestibility and accounted in part for the reduced food quality. In short, ogi from red sorghum is not the most nutritious of the ogi products as previously assumed by the people.

DEVELOPMENT OF SORGHUM BEER: With settlement and civilization came the "brewing industry". Today, the grasses still provide the major ingredients for all the popular alcoholic beverages except wine, - rice is used for sake; cane sugar for rum, corn for bourbon, rye and wheat for other whiskeys and barley for beer. Prior to 1988, all the 32 Nigerian breweries used imported barley malt and with hops, which drained millions of US dollars from the Nigerian treasury. To save the scarce foreign exchange, the Federal Government of Nigeria announced a ban on imported barley effective January, 1988 making it mandatory for scientists and manufacturers to find local substitutes for the imported raw materials. Late Professor Ogundiwin (Food Science & Technology) had studied the production of local ale, "otika", from sorghum in 1977 and this formed a convenient starting point for the group's research efforts summarized in Figure 2 below.

SORGHUM GRAIN: Our investigation of the grains revealed (Osuntogun et al., 1989) that 14 of the 15 cultivars had a low tannin, total polyphenol and cyanide content. During steeping and malting, tannin and polyphenol content decreased while cyanide content increased. The result suggested that all the sorghum cultivars except SRN 4841 could be used for malting with a note of caution about the cyanide potential.

STEEPING: Steeping Nigerian sorghum cultivars in ammonia solution for various time intervals minimized malting loss but at the expense of the more important development of the hydrolytic enzymes and inhibited growth completely at 0.3 M concentration. We therefore concluded that, unlike the report of Khan et al., (1977) on Indian sorghum cultivars, the use of ammonia in steeping process for Nigerian sorghum cultivars prior to malting is counterproductive except where the malt produced is intended to provide malty flavour only (Ilori and Adewusi, 1991).

Figure 2: Process Flow Diagram for the Production of Malted Sorghum and Beer And Contribution from the Ife Group.



MALTING PROCESS: This is a controlled process of germinating the steeped grains in the dark and is thus similar to the production of etiolated seedlings. The production of cyanide potential is linked to the establishment of the acrospires during growth and could become a health hazard to producers and consumers of the product (Adewusi, 1983). The chemical and biochemical changes in sorghum cultivars included a decrease in the crude protein content of the sorghum grains; an increase in the amino and soluble nitrogen, protease activity (about six fold) and diastatic power. Based on these observations, we concluded that virtually all the improved varieties of sorghum could be used in the brewing industry (Ogundiwin et al., 1988).

MASHING PROCEDURE: The first question addressed in this section was if the substitution of sorghum malt for barely malt would necessitate costly changes in the breweries' unit operations? To answer this question, standard mashing/decoction methods were compared with a locally developed "Ife mashing method" and tested on local white and red sorghum and barley malts. Analysis of wort for reducing sugars, percent yield and absolute viscosity showed that the three-decoction and Ife methods gave statistically similar results, while percent sucrose was higher for the three-decoction method. Colour was deeper and pH marginally higher for the three-decoction method. Both methods however produced wort whose physical and chemical qualities were significantly higher than those of other methods. Barley malt of course gave statistically higher values for all the wort properties than sorghum malt though the values from the latter malt also fell within acceptable ranges for the industry. The mashing methods, which involved boiling the acidic wort was found to reduce the cyanide content by up to 90 % making the malt drink and beer from sorghum safe for consumption (Ogundiwin et al., 1988). In a follow-up study (Ilori et al., 1991), we reported that sorghum malt plus 20 % maize grit as an adjunct produced beer of comparable properties with those found commercially. The brew from sorghum malt and 20 % sorghum flour also gave wort of lower extract yield and alcoholic content but still met the Nigerian standard.

TEST RUN OF SORGHUM BEER PRODUCTION: The basic and applied research described above and the Ph. D dissertation of Prof. Ilori paved the way for the demonstration of the commercial production of a sorghum malt based lager beer at the International Breweries Plc, Ilesa (Ogundiwin et al., 1990). I must say at this point that this is one of the few research efforts that have been translated into a commercial reality within the shortest possible time.

THE SPENT GRAINS: The spent grains obtained from malted sorghum were bound to be different from that from barley malt and this was investigated. Adewusi and Ilori (1994) reported the proximate composition of spent grains from sorghum malt and maize grit; the amino acid composition and its bioassay. We then concluded that in the developing countries where malnutrition seems endemic, spent grains obtained cheaply from white sorghum malt could become a good source of additional protein if incorporated into baked products and food blends. Indeed, the addition of 10 % spent grains into wheat flour produced brown bread very similar to that of whole wheat and equally accepted by the taste panel.

LEGUMES: THE MEAT OF THE POOR.

The first cultivated plants were the grasses while seeds from wild legumes were collected. Archeological evidence showed that some cultivated legumes in the Near East appeared almost as early as wheat and barley while the first cultivated legumes appeared in Peru before 6000 BC antedating the appearance of maize. In the Far East, soybean became an early-domesticated plant. Thus if the cereals are given the credit for making civilization possible, its (civilization) advancement could not be nearly as rapid without the legumes. Not only are the legumes high in protein, but their amino acids neatly complement those of cereals.

THE DEVELOPMENT OF ACACIA SEED BASED DIETS IN WEST AFRICA.

Drought is a common occurrence in the Sahel region of West Africa. Widespread failure of the staple crops - millet and sorghum - occurs frequently following low or erratic rainfall resulting in hunger and starvation. Australia, the world's driest continent, has a diverse range of plants suited for the arid and semi-arid regions. These include the fast growing phyllodenous Acacia species of which about 50 (species) are known to have been significant seasonal components of traditional Aboriginal diets. This makes Acacia an old food. Some of these acacia species were already growing in West Africa and have displayed excellent survival, growth and seed production (Rinaudo et al., 1995). Acacia trees flower around October and the seeds are ready for collection as from February when food supply is at its lowest level and farmers have very little to do on the farm. Mr. Vice-Chancellor, Sir, during my sojourn in Canberra, Australia, there was a massive thrust by the Australian Tree Seed Centre (ATSC) to investigate and promote acacia seeds to a famine or staple food in Sahelian Africa. As a seasonal component of Aboriginal food only, there was the need to investigate acacia's chemical, nutritional and safety parameters on long term basis, evaluate its incorporation into local diets and its acceptability by Africans. This was the genesis of a ten-year research effort between ATSC/CSIRO, MIDP in Maradi (funded by SIM International), Niger Republic and my group here at Ife.

Chemical analysis of the acacia seeds as reported by Adewusi et al. (2001a) indicated high crude protein content (21.4-30.6 %). Total dietary fiber was also high (31.9 - 47.9 %) because of the presence of a tough seed coat while ethanol soluble sugar was 9.0-14.6 %. Amino acid content and protein digestibility - corrected amino acid score indicated that tryptophan is the limiting amino acid in acacia seeds followed by the sulfur amino acids. 9, 12 - Octadecenoic acid (linoleic acid) is the most abundant fatty acid (32-56 %). Acacia seed is low in

provitamin A but high in vitamin B complex (thiamine - 0.30 - 0.34 mg/100g; riboflavin 0.21 - 0.36 mg/100g; niacin - 2.9-4.2 mg/100g; and pantothenic acid 390 -1500 mg/100g).

Nutritional evaluation of A. colei and A. tumida seeds (Adewusi et al., 2001b) showed that the latter supported growth and a robust health while A. colei had only average performance. Enzyme indicators did not suggest any liver disorder in acacia fed animals but a mild nephrotoxicity was indicated. Haematoglogical results indicated that anemia was apparent and the natural defense system appeared under stress as indicated by the below normal white blood cell and lymphocyte counts in A. colei fed animals.

Supplementation with 0.2 % DL-methionine significantly increased weight gain, protein efficiency ratio (PER) and net protein retention (NPR) of the rats while DL-tryptophan failed to promote growth in direct contrast to the protein digestibility corrected amino acid score. With the positive response of animals fed methionine supplemented Acacia seeds, it was safe to assume that a methionine rich carbohydrate such as acha or protein (soybean) would be a good complement in acacia based diets for human consumption.

This led us to the complementation studies (Adewusi et al., 2001c). The common sources of carbohydrate in West Africa including millet, sorghum, acha and cassava were incorporated into A. colei seed based diets. Weight gain and protein efficiency ratio were highest in animals fed acha-acacia based diet. Those fed sorghum-acacia diet performed better than those fed millet-acacia while cassava-acacia and corn starch-acacia control diets resulted in morbidity and mortality. This result indicated that the cassava-acacia food combination might not be suitable as a major component of human diet. So far, the experiments carried out were on short-term (28 days) basis.

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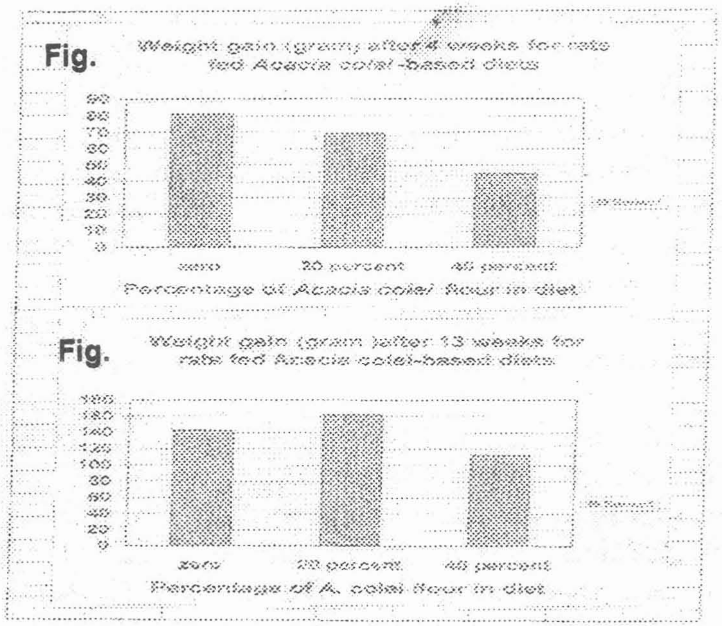
There was the need to investigate longer-term safety parameters. Thus animals were fed three levels (0, 20 & 40 %) of A. colei seed flour in millet based diets for 13 weeks (Adewusi et al., 2001d). Each diet supplied 14.9 % protein and 9.3 % dietary fiber. There was no incidence of morbidity or mortality beyond loss of hair in 20 % of the animals fed 40 % acacia diet at four weeks and in 10 % of the rats fed 20 % acacia at 9 weeks. Growth rate, weight gain, efficiency of feed conversion, protein efficiency ratio and net protein retention were higher in the control group during the first six weeks but by the end of the experiment, animals fed 20 % acacia based diet had superceded the other treatments in these parameters (Figure 3).



Rats fed 40 % acacia based diet performed poorly in all respects compared to the other treatments. Urinalysis of animals fed 20 % acacia in the diet suggested a profound effect of this treatment on the kidney otherwise the activity of other enzymes were in the normal

range. Plasma bilirubin level increased with acacia levels while GPT activity was significantly raised in the rats fed 40 % acacia diet. Haematological data indicated that the treatments had no apparent effect on the RBC level but a profound reduction of the WBC content. In addition, animals fed 40 % acacia diet had neutropenia, lymphocytosis and basophilic leucocytosis which suggested that acacia at 40 % in the diet may be mediating an inflammatory process. We therefore concluded that it was safe to incorporate about 20 % acacia seed flour into the human diet. In addition, acacia at 40 % incorporation could have serious adverse effects exemplified by a gross distortion in the structure of the testes of rats fed 40 % acacia diet for 13 weeks. This result may have been an artifact due to unavoidable delay in tissue processing for histological investigations. It is however well known that seeds such as the cotton seed meal, with very good nutritional values, may contain compounds exhibiting contraceptive properties. Our next study (Adewusi et al., 2001e) was therefore on the reproductive performance of animals fed Acacia colei seed diets. Three sets of animals were raised on acacia based diets at 0, 20 and 40 % acacia incorporation for three generations. The crude protein content was 12.6 % in the diets of the first generation. Weight gain decreased with increasing levels of acacia incorporation and when the animals were mated 13 weeks after weaning, rats on 0 and 20 % acacia became pregnant and delivered an average of 5-6 litters per rat while none of the female rats on 40 % acacia got pregnant. Was this observation due to a yet unidentified component of acacia seed or merely due to amino acid imbalance? This question was answered by increasing the dietary protein content from 12.6 to 18 %. This increase reversed the reproductive failure in the 40 % acacia group. Second and third generations of rats were raised with the acacia diet supplying 18 % crude protein. Though growth rates of litters among the treatments were similar in the first 64 days of life, litters on the 0 % diet grew fastest thereafter. Rats on the three diets also remained healthy and active throughout the course of the experiment. There were no birth defects and no observed morbidity except for some hair loss in about 20 % of the animals fed on 40 % acacia. The results of this trial showed conclusively that laboratory rats can grow and reproduce successfully on sorghum based feed incorporating high proportions of A. colei seed flour and thus clear the last obstacle to a human dietary trial.

Mr. Vice-Chancellor, Sir, my group went to Maradi, Niger Republic in October 1995 to carry out this most important research using the guidelines published by the Council for International Organisation of Medical Sciences (CIOMS, 1993). The trial protocol was approved by the Ethics in Human Experimentation Committee of the Australian National University, Canberra. Approval to proceed with the trial was also obtained from the National and State governments in Maradi, Niger Republic. Seed flour of Acacia colei was incorporated at 0, 15 and 25 % (w/w) into typical diets of rural people of Maradi, and fed to three separate groups of 18 volunteers (nine male and nine female volunteers) for three weeks. Acacia seed flour replaced millet, sorghum and maize flour in these diets. The result showed that there was a significant increase in body mass index (BMI) and mid-arm circumference for the groups fed 15 and 25 % acacia but not for the control (Table 2). Energy consumption was highest for volunteers fed 25 % acacia diets at 65 % and 100 % above the calculated daily energy requirement for male and female volunteers respectively. Plasma enzymes and other indicators of toxicity indicated that there was no adverse effect of incorporating up to 25 % acacia seed flour in the traditional diet. Haematology and urinalysis also supported the view that acacia seed is safe for human consumption at levels up to 25 % (Adewusi et al., 2001f).

IMPLICATION OF THE RESEARCH TO THE WEST AFRICAN SUB-REGION

Rural people in Maradi often resort to eating 'famine foods' including millet and sorghum chaff the bark and leaves of trees and any seed that is not known to be poisonous during periods of famine which occurred in the Maradi region of southern Niger Republic in 1973-75, 1984, 1988, 1994 and 1996. Acacia is therefore the ideal famine food and in normal times, a fair supplement to other food crops. Other attributes of Acacia include

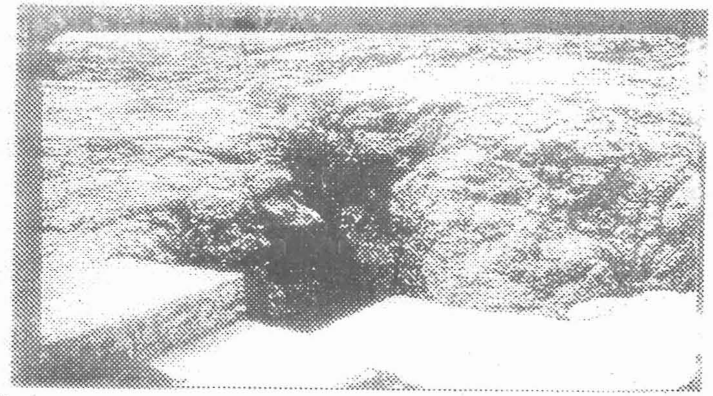
1. Ability to grow on poor, denuded soil.
2. At a period, when desertification is moving southwards at a speed of about one kilometer per annum, acacia could be the ideal leguminous cover for waste land regeneration (see Figure 4).
3. Acacia trees, when coppiced, can provide firewood and thus prevent indiscriminate tree felling for that purpose.
4. Seeds can be used for human consumption or to feed animals thus improving the protein supply for the masses. The situation in Maradi as of 1995 was that over 100,000 Acacia colei trees have been planted and more were being sown with the seed increasingly incorporated into the traditional fare of the people. Such Acacia foods include chin-chin, fura, tuwo, kunu, pancake, masulali, spaghetti and even a coffee substitute café d'acacia made from roasted acacia seeds. Some of these food products are being produced commercially at cottage industry level and acacia may soon be able to provide food security for the entire area and even become a foreign exchange earner.

Table 2: Anthropometric measurements and indices of three groups of male and female volunteers fed 0, 15 and 25 g/100 g acacia-incorporated diets[1,3].

PARAMETERS	MALE			FEMALE		
g acacia / 100g diet	0	15	25	0	15	25
N	9	10	9	9	9	9
Age, y	9 ± 1.2	27 ± 1.0	28 ± 0.8	22 ± 1.9	23 ± 1.2	24 ± 2.0
Height, m	1.7	1.7	1.7	1.6	1.6	1.6
Final weight, kg	59 ± 1.5	61 ± 2.2	65 ± 2.2	48.5 ± 1.4	53.4 ± 1.8	52.4 ± 1.8
Initial weight, kg	58.6 ± 1.5	59.8 ± 2.1	62.7 ± 2.1	48.2 ± 1.5	50.8 ± 1.7	49.8 ± 2.0
% Difference[2]	1.0^a	2.2^b	3.7^c	0.6^a	5.5^b	6.2^b
Final BMI kg/m^2	20.6 ± 0.3	21.9 ± 0.6	21.5 ± 0.6	19.3 ± 0.3	21.0 ± 0.7	20.5 ± 0.7
Initial BMI kg/m^2	20.6 ± 0.3	21.5 ± 0.6	20.8 ± 0.7	19.1 ± 0.3	19.9 ± 0.8	19.4 ± 0.7
% Difference[2]	0.0^a	1.9^b	3.3^c	1.0^a	5.5^b	5.7^b
Final MUC, cm	29.8 ± 0.7	30.4 ± 0.7	31.3 ± 0.7	25.6 ± 0.5	27.2 ± 0.7	28.4 ± 0.8
Initial MUC, cm	29.6 ± 0.6	29.5 ± 0.6	30.0 ± 0.6	25.4 ± 0.6	26.4 ± 0.5	26.7 ± 0.7
% Difference[2]	0.7^a	3.1^b	4.7^c	0.8^a	3.0^b	6.4^c

[1] **Values are means ± SEM**
[2] **Percentage Difference between Initial and Final Values**
[3] **Figures with the same superscript are not significantly different**

Figure4: West Land regeneration using Acacia Plants



View (1982) of check-dam built to arrest gully erosion and retain rainwater

View (1992) of the same check-dam

Source: Patel, 1993. Project Ecolake, India.

ANTINUTRITIONAL FACTORS IN LEGUMES AND VEGETABLES

An early appreciation of the value of the pulses can be found in the Holy Scripture - Daniel 1 verse 12 "And let them give us pulse to eat and water to drink". Legumes contribute 6.4 million tons of protein or about 10 % of the world's vegetable protein and constitute a substantial percentage of the total protein intake in Nigeria. Some of the widely grown and eaten legumes in Nigeria include cowpea (Vigna unguiculata), African yam bean (Sphenostylis stenocarpa), lima beans (Phaseolus lunatus), hyacinth bean (Lablab niger), soybean (Glycine max), bambarra groundnut (Voandzella subterranea) and pigeon pea (Cajanus cajan). All legumes are generally high in protein (18-43 %) but deficient in methionine and in addition contain factors such as tannins, trypsin inhibitors, phytate, cyanogenic glucosides, glucosinolates and flatus inducing oligosaccharides.

In the late 1980s, we realized that the literature on the content of anti-nutritional factors of the important legume grains consumed in Nigeria was scanty and some information simply non-existent. We therefore set out to fill these gaps. I collected samples of the widely grown and eaten legumes in Nigeria and analysed them for anti-nutritional factors. Our results (Adewusi & Osuntogun, 1991) indicated that the trypsin inhibitor activity was generally high in raw grain legumes (highest in soybean). Tannin was also found to be a significant constituent of legume grains especially in those samples with dark seed coat colour. Heat treatment, especially cooking, destroyed the trypsin inhibitor activity by 96-100 % but the effect of cooking on tannin content varied within and among the varieties investigated. For instance, cooking had no appreciable effect on the tannin content in some cowpea varieties while reducing tannin content in some other varieties by up to 68 %. Tannin in African yam bean was reduced significantly (57-94 %) by cooking while the sample with a low tannin content was

unaffected. Tannin is heat stable so the only possibility is that of tannin polymerisation and/or tannin - protein interaction making the tannin insoluble in methanol and therefore undetectable by the assay method used. Removal of the cooking broth before mashing reduced the assessable tannin content, in some cases by up to 50-82 %, thus increasing the potential food value of such legumes. Soaking and/or dehulling the legumes increased the TIA level in some samples by 8-22 % but reduced that of tannin almost entirely. Tannin is generally associated with the seed coat and its removal should eliminate this toxic constituent and improve the nutritive value of "akara" and "moinmoin". In vitro digestibility was low for all the raw legumes due to the presence of the TIA ($r = -0.61$) and tannin ($r = -0.54$). Cooking, as expected, increased the digestibility of all the legumes. Digestibility correlated negatively with the extractable tannin content ($r = -0.86$) indicating that any protease inhibition in the cooked samples would likely be due to the tannin content. That tannin decreased digestibility is not new. In 1987, we (Osuntogun et al.) reported that the tannin content of some 13 leaf protein concentrates (LPC) had an inverse relationship with the protein efficiency ratio ($r = -0.93$) and digestibility ($r = -0.91$) and FDNB-available lysine ($r = -0.67$) of the LPC. The poor growth performance of animals on the LPC with high tannin content were then explained on the basis of

Poor feed intake by animals caused by tannins because of its astringency

Inhibition of digestion by tannin by complexing and precipitating hydrolytic enzymes

Inhibition of absorption

Tannin - lysine interactions and

The adverse effect of tannin on the general metabolism of animals since 5 % tannic acid in a diet is lethal to rats and 1 % is enough to effect some biochemical changes including the increased excretion of kidney enzymes in the urine.

MAILLARD REACTION IN FOOD SUBSTANCES: We have made several allusions to reactions with lysine so let us turn our attention briefly to a typical reaction and its effect on the nutritive value of foods. Lysine is one of the essential amino acids that cannot be synthesized by animals that have to depend on the dietary source for their requirement. Lysine is a basic amino acid containing a very reactive S- amino group. This reactive S- amino group reacts with reducing sugars in what is termed Maillard reaction, which occurs frequently under mild conditions of storage or processing. In addition to Maillard reaction, lysine reacts with the carboxyl group of aspartic and glutamic acids forming an isopeptide (Varnish and Carpenter, 1975, Hurrell et al., 1976). The preparative procedures of most foods involve exposure of the food items to heat. Maillard reaction is expected to occur with a resultant decrease in the available lysine content and protein digestibility of the food. It is on this basis that we investigated the effect of heat on the digestibility and available lysine of some model foodstuffs. Our model systems (Adewusi and Oke, 1984) included Conophor seeds to represent a naturally occurring protein - carbohydrate - oil complex, Amaranthus leaf protein concentrate (LPC) - cassava and LPC - glucose mixtures as models for food protein - carbohydrate mixtures. Results indicated that heating Conophor seeds at 121oC for 24 h reduced digestibility by 60-100 % while that of the LPC went down to 0 % by both pepsin-pancreatin and papain digestion methods.

Results on the available lysine content indicated the following:

1. Cassava - LPC mixtures of ratio 1:2 seemed to be most affected, losing 45 % of the available lysine after heating for 24 h at 121o C.
2. About 80 % of the available lysine content was lost when glucose - LPC mixture (ratio 1:2) was heated for 24 h at 121oC. This showed that the deleterious effect of the Maillard reaction increased with the presence of reducing sugars.

3. When LPC was heated alone, about 45 % of the available lysine was lost in 24 h.
4. The effect of heat on available lysine content of Conophor seed was similar to that obtained for glucose - LPC mixtures (72 % available lysine was lost in 24 h).

We then concluded that the effect of heat on digestibility and available lysine increases with time and the presence of reducing sugars. It appeared that Maillard reactions will be insignificant in cassava based diets because it (cassava) has a low level of reducing sugars.

Our next study (Adewusi and Oke 1985) evaluated the nutritional quality of acetylated casein in maize meal, corn starch and cassava based diets. Casein was acetylated with acetic anhydride/sodium acetate with 98.5 % acetylation. The nutritional value of maize and cornstarch meals decreased with increasing incorporation of acetylated casein but in the presence of cassava, the nutritional value of the modified casein was enhanced. Acetylated casein was used as a model to study the effect of "tied-up" lysine in the diet on the growth of rats and showed that cassava by some mechanism unknown enhanced the nutriture of the diet.

In a follow-up study, we (Adewusi et al., 1991) studied the available lysine and reducing sugar content of the commonly eaten legume seeds and products in Nigeria. This project was necessitated because of the different cooking periods of the legume seeds and the period the product stays on fire in commercial establishments. The results indicated that the available lysine of most raw legumes falls within the FAO (1970) values for these legumes. Cooking the legumes reduced the available lysine content by 6 % to 53 %, which generally depends on the cooking time.

The results of the crude protein and available lysine content of some of the legume products sold commercially indicated that all the products contained acceptable levels of crude protein but the available lysine content was reduced by 14 - 38 % as a result of prolonged cooking as shown below (Table 3).

TABLE 3: CRUDE PROTEIN AND AVAILABLE LYSINE CONTENT OF SOME SEED PRODUCTS AS EATEN IN NIGERIA[b].

Food Sample	% crude protein	Available lysine g / 16g N		
		Raw	Cooked	% Loss
Pigeon pea seeds + maize + pepper + palm oil + salt	16.9	5.8c	4.5	22.4
African yam beans + maize + pepper + palm oil + salt	19.4	5.3c	4.1	22.6
Cooked beans (top portion)	19.9	5,8	5.0	13.8
Cooked beans (scrap of the pot bottom)	21.2	5.8	3.6	37.9
Light brown bean balls (akara)	17.3	5.8	4.5	22.4
Dark brown bean balls (akara)	18.6	5.8	4.0	31.0

Source: Adewusi *et al.*, 1991

Lysine is the first limiting amino acid in cereals but not in legumes. A loss of about 40 % of the available lysine in maize-legume combination may make lysine the limiting amino acid thus reducing the food value of the product. It is therefore advisable to cook our legumes with a

pressure cooker to reduce the cooking time and use adiabatic containers ("warmers") to keep the products warm instead of keeping the foodstuffs permanently on fire until exhausted.

THE TROPICAL FRUIT & ROOT CROPS

Mr. Vice-Chancellor, Sir, this great citadel of Learning and Culture is situated in the rain forest zone, which is the breadfruit basket of Nigeria. The breadfruit tree (Artocarpus communis Forst, Family: Moraceae) is native to Malaysia where it served as food for the Polynesians. Breadfruit spread in the prehistoric times throughout the tropical south Pacific and the Caribbean, where it was and is still planted as a staple food (Loos et al., 1981). The breadfruit plant was introduced to Ifewara in southwestern Nigeria from the Caribbean before the turn of the 19th century and spread to Ile-Ife and her villages but not beyond because it is regarded as a poor man's substitute for yam. I have estimated that Ifewara alone could potentially produce 8 million tons wet weight of breadfruit a year and southwestern Nigeria has a production potential exceeding 100 million tons wet weight every year (Adewusi, unpublished results). This obviously shows the high potentials of breadfruit as a source of food as well as industrial raw material.

My first publication (Omole et al., 1978) as a young lecturer in this university compared the nutritive value of six tropical fruits and tuber crops at a level of 30 % in the diets of rats. The best result was from breadfruit closely followed by cocoyam based diet while cassava had the least nutritive value at that level. Yellow yam fared better than the control cornstarch - casein diet which in turn was better than plantain and white yam in that order. Plasma urea varied inversely with the PER thus reflecting dietary protein quality. Plasma thiocyanate - a detoxification product of cyanide - was only significantly high in rats fed cassava based rations. In our subsequent study on weaning diets in Nigeria, (Adewusi et al., 1991), we compared the nutritive value of ogi from white and red sorghum, white and yellow maize with breadfruit and cassava starch as sources of carbohydrate. We found that the performance of cassava starch, breadfruit and cornstarch were not significantly different from one another but better than white and yellow maize ogi which in turn was better than red and white sorghum ogi. In vitro hydrolysis of starch indicated a rapid hydrolysis of breadfruit starch with complete hydrolysis occurring in about one hour. This was the highest rate of hydrolysis and showed the possibility that breadfruit may contain an appreciable amount of low molecular weight carbohydrates. The high rate of breadfruit starch hydrolysis is also consistent with the high feed intake by animals fed breadfruit and the consensus that breadfruit in any form is a light diet. With these results, we felt confident to promote breadfruit for food as well as its starch for use in the textile, pharmaceutical and other industries.

There were, however, a few unresolved issues about breadfruit including the paucity of information about the proximate composition of the different parts of breadfruit and the wide variation between proximate composition and other details on breadfruit from South America and the Caribbean in literature. Our subsequent study was therefore focussed to address the following problems:

1. The proximate composition of components of breadfruit from different locations.
2. The content and composition of starch isolated from breadfruit grown in Nigeria and its physicochemical characteristics
3. The composition of the free sugar and oligosaccharide content and the kinetics of carbohydrate breakdown during breadfruit deterioration under different storage conditions.

Our results (Adewusi et al., 1995) indicated that there was no significant difference in the proximate composition of unripe mature

breadfruit samples from different locations in southwestern Nigeria and that the edible pulp is a good source of starch comparable to other conventional sources. The peel and the core which are waste products at present could also be turned to a money spinner. Flatus producing oligosaccharides which cause accumulation of gas in the large intestine as a result of microbial degradation (and therefore a serious social menace) are virtually absent in the pulp (raffinose is 0.05 %). Stachyose (another flatus-producing oligosaccharide) is absent in both the peel and the pulp while the core has 0.1 % and 0.05 % raffinose and stachyose on dry weight respectively. Total reducing sugar in the pulp was low and should therefore pose very little problem in terms of browning as a result of Maillard reaction. Starch from the breadfruit pulp could be easily and cheaply isolated with 56-60 % yield and a purity of 98 %. The isolated starch from breadfruit should thus be cost effective. If breadfruit starch is found suitable industrially, it would have a multiplier effect. The farmers will have a higher income, the processors (more employment), the industry (cheaper raw materials) and the nation (saving the foreign exchange to import the starch).

The amylose content of breadfruit pulp was found to be 26.9 % significantly higher than the content of many conventional sources of carbohydrate. The 38.3 fold two-stage swelling behaviour of breadfruit starch is higher than those of many cereals. The solubility of breadfruit starch (24 %) also followed a two-stage pattern and compared favourably with that of maize (25 %). Thus, we have presented the industrialist, the developer, the entrepreneur and R & D personnel with the data base on the chemical and physical properties of breadfruit and its isolated starch and compared them with the starch from conventional sources for easier manipulations. There is a negative aspect to breadfruit that needs further research before its final acceptability as an industrial raw material. Breadfruit deteriorates very fast and this limits its utilisation to the immediate environment of its production. Transportation of ripe mature fruits for a few hours very often results in more than 70 % spoilage. Several storage conditions have been tried locally and experimentally but so far the shelf life of breadfruit can not be more than 72 hours. The mode of preservation of breadfruit is a challenge that we shall soon meet.

Mr. Vice-Chancellor, Sir, inadequate funding has always been a problem in research but I am happy to say that Professor Ilori obtained some funds from IFS, Sweden. He was thus able to develop some non-alcoholic beverages from sorghum malt and breadfruit among other adjuncts, study the engineering economy of the production of such non-alcoholic beverages and the prospect and economics of small-scale ethanol production from breadfruit and cassava (Solomon et al., 1994; Ilori and Irefin, 1997; Ilori et al., 1996; Ilori et al., 1997). The R&D on breadfruit is fully established here in Ife and we can provide the database, the expertise and pilot scale demonstration to any entrepreneur who may want to develop breadfruit into any of the several products already mentioned.

THE PARADOX OF CASSAVA: Mr. Vice-Chancellor, Sir, I am aware that at least two of the recent inaugural lecturers (Prof. Ogunsua, June, 2000 and Prof. Ajibola, August, 2000) have extensively discussed cassava from different perspectives. Cassava is a staple food for the over 100 million people of Nigeria and over 500 million people the world over. Cassava ranks fourth on list of major food crops in the developing countries after rice, wheat and maize (FAO, 1989) and has a world production of 120-130 million tons of fresh roots per year. Cassava at a time became the number 1 food in Nigeria but all of a sudden (with "gbemu" from President Obasanjo) cassava has become the rich man's food and number 6 on the list of Nigeria's foodstuffs. Cassava is therefore worthy of all the attention it has been given.

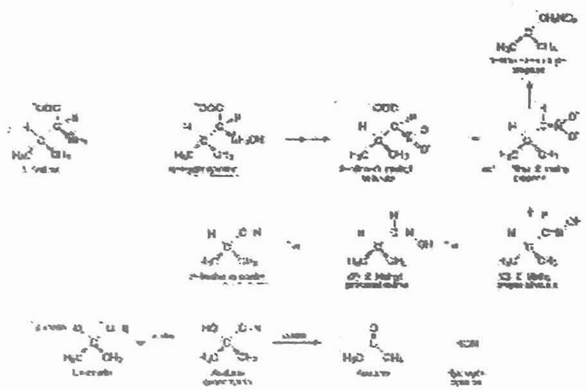
The only serious problem is that cassava synthesizes and accumulates two cyanogenic glucosides, linamarin and lotaustralin in ratio 93:7 in the leaves and roots. These secondary metabolic products on hydrolysis yield glucose and cyanohydrin; the latter on further hydrolysis yields HCN, which is so lethal that 50 mg is fatal to a 70 kg man. It is then pertinent to ask why does cassava accumulate these compounds or alternatively what is the role of these secondary metabolic products in plants? There was a controversy about the role of cyanogenesis starting with Goris (1921) and Robinson (1930) and the controversy remains unresolved till today despite the mountains of scientific evidence (Jones, 1962, 1976; Whittaker and Feeny, 1971; Hughes and Conn, 1976; Seigler, 1977; Lieberei, 1986; Lieberei et al., 1989).

Mr. Vice-Chancellor Sir, I jumped into this muddy environment performing some very simple experiments. I assumed that if plants are "wise" enough to protect themselves then they should be able to do it economically too! I planted Sorghum bicolor seeds and monitored the HCN-potential of the seedling with age. The seedlings synthesized and accumulated its cyanogenic glucoside- dhurrin - right from germination when it is most vulnerable! In addition, the dhurrin content in the first leaf is uniformly distributed but decreases from apex to the base in the second and third leaves. Most of the dhurrin is accumulated in the first leaf, which is closest to the predator. The leaf apex is next in proximity to the small animals and the bitter and poisonous nature of the dhurrin accumulated therein should serve as a deterrent to grazing animals. Labeling studies using 14C-shikimic acid showed that all the tissues synthesized and stored dhurrin. Based on the results of these simple experiments, I (Adewusi, 1985) suggested that cyanogenic glucosides are defensive in nature among other possibilities.

Let us briefly review the biosynthesis of cyanogenic glucosides as a background to my contribution to the knowledge of cyanogenesis in plants. The primary precursors of cyanogenic glucosides are restricted to the five hydrophobic protein amino acids - valine, leucine, isoleucine, phenylalanine and tyrosine and to a simple non-protein amino acid-cyclopentenyl glycine. To date, the most detailed studies spanning over a 4-decade period on the biosynthesis of cyanogenic glucosides have been carried out on sorghum. From the work of Conn and Akazawa (1958) through many generations (Hughes, Moller, Selmar, Butler etc) came the biosynthetic pathway. The biosynthetic pathway in cassava is shown in Figure 5.

The biosynthetic enzyme system in sorghum constitutes a highly organized system providing an efficient mechanism for the channeling of the generated intermediates between L-tyrosine and p-hydroxymandelonitrile in sorghum (Moller and Conn, 1980) or L-valine and 2-Methyl propionitril in cassava. In the late 70s up to 1981; the group in Davis (with Prof. E. E. Conn) also worked out the subcellular localization of dhurrin which is in the vacuole of epidermal cells and its catabolic enzymes resident in the mesophyll cells.

Figure 5: The biosynthetic pathway for the valine-derived cyanogenic glucoside linamarin in *M. esculenta.*



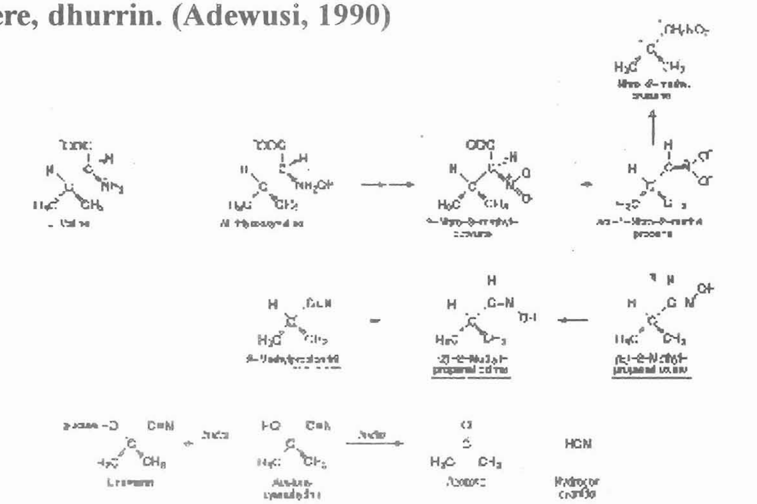
Source: Koch, et al. 1994

These were the exciting years in Davis. I was offered the position of a visiting scientist in Davis in 1980 and through a special training scheme offered by this great citadel of culture and learning, I was able to travel to U.S. in October, 1980 but the party time was almost over by then.

Professor Conn asked if I was interested in the turn-over of cyanogenic glucosides in plants as a project. The scenario was that the phenomenon of compartmentalization of dhurrin and its catabolic enzymes in sorghum should prevent the hydrolysis of dhurrin in vivo. Bough and Gander (1971) however reported a high turn-over rate in etiolated sorghum seedlings while Bediako et al., (1980) also provided qualitative evidence of the turn-over of linamarin in cassava leaves. There was also enough evidence from Prof. Conn's laboratory (Conn, 1994) to suggest a turnover of dhurrin in sorghum seedlings but at what rate?

Glyphosate, N-(Phosphonomethyl)-glycine), is a potent herbicide (Trade name - Round up) which inhibits the shikimic acid pathway (Figure 6) leading to the formation of the aromatic amino acids including tyrosine, the precursor of dhurrin in sorghum seedlings. If glyphosate is a potent inhibitor of the shikimic acid pathway, it is expected that the plant would die off within a few days. We found that glyphosate supplemented with the aromatic amino acids would inhibit dhurrin synthesis in 4-day old sorghum seedlings without adversely affecting other physiological processes for the next 5 days. Exogenous tyrosine is converted to dhurrin at a maximum rate of 3 % so channelization of dhurrin biosynthesis was a bonus in this respect. The glyphosate procedure became an inexpensive method to estimate the turnover of dhurrin in the root and shoot of green sorghum seedlings. Radioactive tyrosine and shikimic acid were also fed to green sorghum seedlings; their incorporation into dhurrin monitored, and the turnover of the labeled compounds studied over a period of time.

Fig. 6: Site of glyphosate action on the shikimic acid pathway leading to the biosynthesis of the aromatic amino acids and from there, dhurrin. (Adewusi, 1990)



The results indicated that the accumulation of dhurrin in the shoot and root followed a multiphasic complex kinetics. We used the first order kinetics equation as an approximation to calculate the rate of dhurrin synthesis (17.4 nmol/h/shoot) - the summation of the rates of accumulation (12.6) and breakdown (4.8 nmol/h/shoot). The rate of dhurrin breakdown therefore represented 27 % of the total cyanide capability of the shoot. In the root, the rate of dhurrin synthesis was 4.1 nmol/h/root while the breakdown rate was 1.4 nmol/h/root, equivalent to 34 % breakdown of the synthesized dhurrin in the root. The experiment on diurnal variation also showed that dhurrin biosynthesis occurred 3-8 times faster in the dark than in the light

photoperiod. These results were then interpreted as substantiating our earlier hypothesis that cyanogenic glucosides do serve both protective and primary metabolic functions; protective in the sense that sorghum seedlings accumulate more dhurrin than it catabolized with the result that the stored dhurrin could act as a deterrent to predators. The primary function of dhurrin in green sorghum seedlings could be through the provision of carbon atoms and the conservation of nitrogen, for example, in the formation of ß-cyanoalanine and asparagine. Furthermore, Moller and Conn (1979) have speculated that dhurrin may also provide carbon atoms for ubiquinone biosynthesis on the basis of the in vitro oxidation of p-hydroxybenzaldehyde to p-hydroxybenzoic acid (a known precursor of ubiquinone in plants). Thus, my report on this work (Adewusi, 1990) became a landmark publication in this small area of cyanogenesis.

THE PARADOX OF CASSAVA TOXICITY.

The continuing interest in cyanogenic glucosides for the past four decades is not so much because of their physiological role in the plant but the effect on man and animals. Some of the diseases associated with the ingestion of improperly processed cassava include a neurodegenerative disorder known as Tropical Ataxic neuropathy (TAN, Osuntokun, 1994), the paralytic disease - Konzo (Tylleskar, 1994), and goitre - (Delange et al., 1994; Adewusi et al., 1992; Adewusi and Akindahunsi, 1994; Akindahunsi et al., 1993, 1998, 2000). Fatal and non-fatal acute poisoning attributed to cassava based meals has been reported in Nigeria, (Ogunsua, 2000, Akintonwa, 1994) in a very minute but significant percentage of the population. With all these, the basic question remains - are cyanogenic glucosides actually toxic? As our friends and colleagues in IITA, Ibadan, used to say, cyanogenic glycoside is not toxic, but it just happens! This means that cyanogenic glucosides may not be toxic until they are broken down to yield HCN, which is the actual culprit. Let me review some of my contributions to the metabolism of cyanogenic glucosides in animals.

One of my first projects, (Adewusi and Oke, 1980) investigated the effect of various levels of cassava on protein utilization by rats. Cassava was substituted for maize starch at 0-100 % level in rat diets using casein as the source of protein. Except at 50 % level, where all the parameters determined were similar to those of the control, the general trend was that PER and in vivo digestibility decreased with increased cassava level while plasma thiocyanate and urea levels increased. Leaf protein concentrate from Amaranthus as the sole source of protein at 100 % cassava level depressed PER but increased (not as much as in the control casein diet) with 0.2 % methionine supplementation. The next project addressed the metabolism of amygdalin in rats. Amygdalin was chosen for two main reasons. First, it was the cheapest cyanogenic glucoside available commercially and secondly, the project was initiated during an era when laetrile (amygdalin) was being touted as a cure for cancer. I reported the mean lethal dose (LD50) of amygdalin to be 880 mg/kg BW by oral administration (Adewusi and Oke 1984a) but when amygdalin at 600 mg/kg BW was administered with ß-glucosidase (the enzyme catabolising the amygdalin) all the animals died. When 200, 400 and 600 mg/kg BW amygdalin were administered to different groups of rats, 2.3, 7.4 and 7.5 mg cyanide representing 12, 19 & 12 % of the dosage were excreted within 48 h respectively. Thiocyanate excreted within the same period was 7.0, 9.1 and 9.5 μmol representing 18, 11 and 8 % of the oral dosage respectively. With 300 mg/kg BW amygdalin administered intraperitoneally (ip), 4 mg amygdalin and 4 μmol thiocyanate was excreted representing 14 and 7 % of the dose respectively. We further found that excretion of intact amygdalin and thiocyanate was uniform over the first 48 h period when the dose was low (200 mg) but with higher doses over 70 % of the excreted products were detected in the urine during the first 24 h. Hydrolysis of a substantial part of amygdalin occurred in the gut. This can be deduced by comparison of the SCN released in the animals fed orally (7.1 μmol was excreted in 200 mg/kg BW) and those administered ip (4.0 μmol in 300 mg/kg BW).

Our second paper (Adewusi & Oke, 1984 b) reported that the organs of 15-day old rats had the highest capability to hydrolyse amygdalin and prunasin and that the activity decreased with age. Furthermore, the distribution of 30 mg amygdalin administered to rats showed that the stomach (0.89 mg), small intestine (0.7 mg), spleen (0.36 mg) and large intestine (0.30 mg) had the highest concentration in the first hour in that order. The highest amygdalin content was however found in the large intestine (0.8 mg) in the second hour. Intestinal microflora are restricted to the large intestine and these produce ß-glucosidase which could hydrolyse amygdalin. After the publication of our two papers, Professor Rauws of the National Institute of Public Health, the Netherlands sent me a long letter and a reprint of his two articles (Rauws et al., 1982). Using beagle dogs as experimental animals, they found that virtually all the 500 mg amygdalin administered intravenously could be recovered intact in the urine within 6 h. Oral administration of 500 mg amygdalin resulted in the production of prunasin which was excreted. In the rat, dosed orally, a lot more prunasin was formed. Rauws in his letter then suggested that what we took to be amygdalin could indeed be prunasin which is amygdalin minus one of its 2 molecules of glucose. Rauws et al. (1982) did not test for SCN in any of their experiments but as shown earlier, ingestion of a cyanogenic glucoside with a source of ß-glucosidase from a plant or microbial source could be dangerous and even fatal. To buttress this claim is the report in literature of two fatal cases of amygdalin ingestion (Humbert et al., 1972; Sadoff et al., 1978) and the fatal and non-fatal acute poisoning attributed to cassava based meals in Nigeria (Akintonwa 1994, Ogunsua 2000).

CYANIDE DETOXIFICATION IN ANIMALS

If we accept the premise that the acute poisoning reported in literature is due to the release of cyanide from the ingested cyanogenic glucosides, how can we account for the diseases associated with the non lethal acute intoxication of cassava and other cyanogenic glucoside-containing foodstuffs? Cyanide is a natural toxin present throughout evolution, therefore human beings possess two or more effective defense lines. Firstly about 10 mg (0.4 mmol) cyanide can be neutralized "by the reversible reaction with the methaemoglobin fraction in the red blood cells". A second route of detoxification involves the enzyme - rhodanese, which is present in most human tissues. Cyanide in the presence of rhodanese reacts with labile sulfur from dietary source (methionine / cysteine) to form thiocyanate (SCN). The conversion rate of cyanide to SCN in well-nourished adults is about 50-100 mg cyanide / 24 h (Rosling, 1994). The rate-limiting step is the availability of dietary sulfur; a malnourished individual could thus be at a greater risk of cyanide intoxication. An insignificant fraction of the cyanide generated in vivo could react reversibly with hydroxycobalamin to form the active cyanocobalamin (Vit. B12). This process has been hypothesized by Oke (1980) to be one of the few beneficial effects of the ingestion of foodstuffs with cyanide potential. It has been estimated that about 80 % of a cyanide load in well-nourished subjects can be converted to the less toxic SCN (Rosling, 1994). Thus we have seen that the toxic cyanide is detoxified to SCN using a dietary source of labile sulfur from methionine and cysteine but these sulfur amino acids are first limiting in legumes - the meat of the poor. The consequence is that the barely adequate dietary status in healthy subjects is reduced. The major question is the role of SCN in the aetiology of certain diseases especially as it is well known that SCN was one of the early drugs used for cancer treatment.

TROPICAL ATAXIC NEUROPATHY (TAN): The commonest signs of this neuropathy are defective perception of sensory modalities usually at the lower limbs, bilateral optic atrophy, ataxic gait and impaired muscular coordination, bilateral perceptive deafness, weakness and wasting of the muscles. Though plasma levels of

thiocyanate, cyanide and urinary excretion of SCN were significantly higher in patients than in controls, the exact pathogenesis is uncertain. However by strength of association, consistency, dose-relationship and biological plausibility, it seems from circumstantial evidence, that cassava diet is the major cause of TAN (Osuntokun, 1994).

KONZO (OR SPASTIC PARAPARESIS) - meaning paralysis of both legs is another form of neurological disability. The onset is characterized by an abrupt paraparesis occurring within minutes or hours in a healthy person. Several epidemics of Konzo have been reported among rural populations of Mozambique, Tanzania, Zaire and Central African Republic (Howlett 1994, Tylesskar, 1994). Again, the epidemiology of Konzo is probably induced by cyanide derived from insufficiently processed cassava, in combination, with a deficiency of sulfur amino acids in the diet. Let us now turn our attention to something induced by SCN.

THE GOITER PROJECT: Cassava was first shown to be goitrogenic by Ekpechi (1967) and Ekpechi et al., (1966) and has also been demonstrated in Bas Zaire, Kivu and Ubangi in Zaire (Delange et al., 1994). A preliminary survey by Oke et al., (1988) showed that the incidence of goiter in Akungba and Oke-Agbe of Akoko division of Ondo State was as high as 20 % while that of Erinmo and Ifewara in Ijesha division was about 2 %. Figure 7 shows a typical goiter patient and the probable cause (Cassava).

Fig 7: Goiter patient under medical examination and heaps of cassava in the market at Akungba, Akoko, Ondo State.

We therefore investigated the chemical, dietary and environmental factors that were responsible for the goiter endemia in comparison with the Ijesha division as the control locations. Urine was collected from all the locations and analysed for thiocyanate (SCN), iodine, urea and creatinine. Blood was also collected, the serum separated and analysed for triodothyronine (T3), thyroxine (T4), thyroid stimulating hormone (TSH) and thyroxine-binding globulin (TBG). Water samples from the rain (stored for drinking), streams and wells were collected and analyzed for iodine content. Raw and cooked foodstuffs as well as typical breakfast, lunch and supper of subjects were collected and analyzed for iodine, crude protein, gross energy, cyanide and glucosinolate content Commercial table salts sold in the

open markets of all the locations were bought and analyzed for iodine. We also carried out a model study using rat bioassay to test the hypothesis of low iodine - high cyanide - low protein synergism in the aetiology of goiter in Oke-Agbe and Akungba. For this purpose, Amaranthus viridis a very popular vegetable in Akoko division was included as a protein source at 10 and 3.5 % C. P. respectively.
Some salient research findings about the dietary intake in the test and control locations (Akindahunsi et al., 1993) include

1. Typical breakfast was yam and cassava in Akoko and maize gruel and rice in the Ijesha area. Lunch and supper in Akoko were mainly cassava and cocoyam based; in Erinmo, they were yam and Ifewara - breadfruit and / or yam - based.
2. Dietary iodine intake was low ranging between 6 - 8 % of the recommended daily allowance of 150mg in all the sites investigated. All the villages lacked pipe - borne water; rain - the main source of drinking water in Akoko - contained low levels of iodine while water from wells and streams contained intermediate levels. All table salts except Dicon were disappointingly low in iodine.
3. Mean daily intake of protein varied between 11 and 13 g which is 17 - 21 % of the RDA of 62 g.
4. The average calorie intake was 1486 kcal, which was just above 58 % of the average British intake.

The very low level of nutrient intake would therefore predispose the population to protein-energy malnutrition which would be exacerbated by the fact that the major sources of protein, the plant products, are usually deficient in methionine - a limiting amino acid that is also needed for cyanide detoxification. Amaranthus viridis - a common vegetable in Akoko area contained about 1 % glucosinolate per wet weight and the hydrolysis is expected to add to the SCN overload.

The chemical and biochemical study (Akindahunsi, 1992, Akindahunsi et al., 1999, Akindahunsi and Adewusi, 1999) confirmed significant regional variations in the urinary levels of iodine and thiocyanate while there was no significant difference in urea and creatinine levels. Urinary iodine level was higher in all Nigerian locations compared other African locations where goiter is endemic and even some control populations. The same goes for the urinary iodine/creatinine ratio. Thus the important role of iodine deficiency as a permissive factor in endemic goiter does not seem to hold in the Akoko incidence. A similar situation was found for urinary SCN/Creatinine, I/SCN ratios. Thus,

(a) The chemical parameters of goiter proposed and extensively used before this study may only hold for rural populations where subsistence farming is the only occupation. In towns with a mixed population like Akungba (Pop. 23,597 in 1986 and Oke-Agbe (Pop. 19,835), the presence of endemic goiter may be masked when the mean ratios for the whole population are used. A breakdown of the ratio may prove more informative about the thyroid status of the less privileged.

(b) Thiocyanate overload seemed to be the major cause of goiter in Akungba while that of Oke-Agbe could be attributed to low iodine ingestion in the presence of a relatively high thiocyanate overload (Akindahunsi et al., 1994).

(c) Protein malnutrition seemed to play an important role in the aetiology of goiter in both Akungba and Oke-Agbe and probably acts in synergism with low iodine and high thiocyanate load.

(d) Finally that the incidence of goiter was low in the control area because cassava intake (cyanide exposure) is lower and iodine ingestion apparently higher than in the test locations. The control population however remains at risk of goiter endemia if they are more exposed to cyanide ingestion as could occur during drought and / or crop failure.

OCCUPATIONAL HAZARD IN CASSAVA PROCESSING:
During the course of this investigation, we realized that cassava processing which until recently was a vocation for a few uneducated women, had become a booming business with cottage industries in homes or as abutment to homes. Most processing 'huts' or workshops are ill ventilated thus exposing the processors to the risk of a non-dietary source of cyanide. We therefore decided to carry out a survey of cassava consumption among cassava processors in comparison to students from traditional (Ile-Ife) and non-traditional (Akure) cassava-consuming environments. Blood and casual urine were collected and analysed for SCN. Our results presented in Table 4. indicated that a large proportion (64 %) of our students here at Obafemi Awolowo University, Ile-Ife consume cassava products at least once a day compared to 38 % in FUTA and 44 % among the cassava processors. Contrary to all expectations, the serum SCN level in cassava processors was significantly higher than those in the students though renal clearance was about the same.

Table 4: Frequency of Cassava Consumption per week and Serum and Urinary SCN levels in Cassava workers and Students at O.A.U, Ile-Ife and FUTA.

Frequency per week	Cassava processors (%)	O.A.U. students (%)	FUT, Akure students (%)
1 – 3	28	32	27
4 – 6	28	4	35
≥7	44	64	38
Serum*mg/dL	0.57 ± 0.08^a	0.38 ± 0.07^b	0.37 ± 0.02^b
Urine* mg/dL (n)	0.34 ± 0.04^a (25)	0.38 ± 0.05^a (25)	0.35 ± 0.02^b (118)

*Mean ± SEM Source: Adewusi and Akindahunsi (1994).

This tends to show that cassava processors are exposed to an increased danger of cyanide toxicity as an occupational hazard. Our analysis of cassava products - gari, lafun, and fufu indicated low levels of cyanide potential, so our people can eat as much cassava products as possible provided they are properly processed. However, it would be a different story if the processing period is reduced drastically, as commonly practiced among the commercial processors who go after profit rather than the health of the consumers.

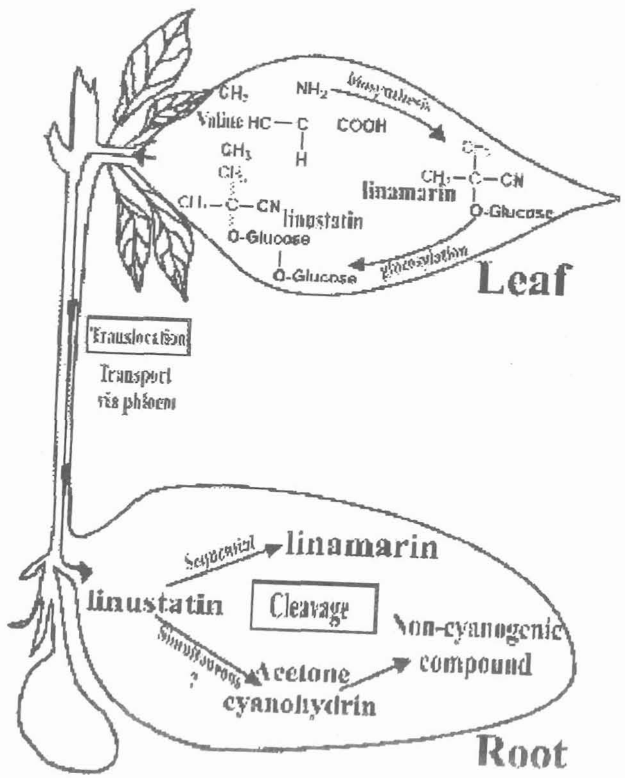
CASSAVA AND BIOTECHNOLOGY: If cassava is a problem food as portrayed above, why do we continue to eat it? Cassava is already established in our *TRADITION* as food, we are already used to the taste of cassava products and the food security it provides all the year round. A well-processed cassava product is as safe as wheat or maize foods. The instances of high cyanide exposure from cassava based diets mainly occur in unstable and changing societies due to underlying social instability, agro-ecological crisis, war and food scarcity. For instance, in the late 1950s, & early 1960s till the era of the country's oil prosperity in the 1970s, cassava was widely regarded as a poor man's food and "bad" for vision. It was therefore rarely eaten and actively discouraged by parents who would not want to spend on vision aids for their children. With the down turn in the national economy and its attendant loss of employment, cassava again came to the ascendancy and worse, commercial processors started cutting corners, the time taken from grating through fermentation to frying gari has been reduced to 48 h or less. In East and Central African countries, war, drought and food insecurity resulted in insufficient processing of cassava products with the attendant fatal, near fatal, or chronic toxicity syndromes. What then is the economic prospect for Africa in the near future? The GATT agreement signed in 1993 is

certainly not in favor of the developing countries therefore per capita income level may reduce in this decade. This will increase the cassava eating population and so will the number of people who will encounter unacceptably high rates of cyanide exposure. If the present 300 million cassava eaters increase and they cannot but eat cassava, then something has to give! This places a major responsibility on Scientists. As a short term solution, improved processing techniques must be developed and processing of cassava rigorously monitored by health officials. The long-term solution to the toxicity problem is fundamental research at the molecular level to produce a non-cyanogenic cassava or cassava with cyanide potential at specific organs where it will do the least damage to consumers. In short, I am proposing the development of a new food using biotechnology and genetic manipulation. This is not an entirely new concept so let us briefly look at how it can be achieved.

The major site of the biosynthesis of linamarin and lotaustralin is the leaf through the pathway shown in Figure 3. Interference at the first step of the biosynthetic pathway is a feasible option. Blockage or removal of the key enzyme catalyzing this vital step of commitment through genetic engineering will eliminate all of the cyanide potential of cassava probably without affecting the plant's primary and secondary metabolism. Professor Moller and his colleagues have purified and characterized the enzyme complex - cytochrome P-450-dependent monooxygenases responsible for the first 3-4 steps of the pathway. The cDNA of this enzyme complex has been worked out and expressed in Escherichia coli (Koch et al., 1994). This is the culmination of 15-20 years' fundamental research and a totally non-cyanogenic cassava may be produced in another 10 years.

The alternative route shown in Figure 8 below involves the Linustatin Hypothesis. As pointed out earlier, linamarin is produced in the leaves but stored in the roots. Transport of linamarin cannot occur because of the occurrence of its catabolic enzymes - ß-glucosidases and ahydroxynitrile lyases - in the apoplastic space. The linustatin hypothesis simply proposes that linamarin is glucosylated in the leaf to form linustatin which is then translocated to the roots. In the root, a sequential diglucoside is thought to cleave off the glucose to give linamarin, which is then stored. If an enzyme responsible for the glucosylation of linamarin in the leaf can be found and purified, then using genetic manipulation it is possible to knock this enzyme off in the leaves.

Fig. 8: A schematic representation of the Linustatin Hypothesis (Adapted from Selmar, 1994)



Without the glucosylation step, linamarin cannot be translocated to the root (Selmar, 1994). A new cassava with a lot of cyanogenic potential in the leaf but none or very little in the root will then be produced. This alternative route has many obstacles to cross as we are still at the stage of establishing the hypothesis beyond doubt. I was lucky to work with Dr. Selmar on this problem during my study leave in Germany in 1993-94. During that period, I was able to detect marked activity of a sequential diglucosidase in cassava roots. This enzyme, which converts linustatin to linamarin and glucose, shows optimal activity at pH 4.5-5.0 and is Mn2+ dependent. Despite the promise of a rich research harvest and the breaking of new grounds, I could not continue this line of research on my return to Nigeria due to a gross lack of facilities.

Let us turn away from this sad event and review more of my research activities but I'll be brief because of time constraint.

DELICACIES: These are special parts of meals either due to their being scarce and therefore expensive and / or because they have special flavour, aroma, religious or cultural significance. Mushrooms are often harvested and eaten by the rural population of Nigeria but the cooking procedure differs from place to place. For instance, in many parts of southwestern Nigeria, the mushrooms are added to the stew last and allowed to simmer for a few more minutes. There is no doubt that mushrooms can be delicious and often contain a high level of crude protein. However, our investigation on the nutritional, teratogenic and toxic nature of some wild edible mushrooms calls for caution and at least careful processing. Mr. Vice-Chancellor Sir, In the course of Dr. (Mrs.) Alofe's research work for her Ph.D degree in Microbiology and some follow-up study, we fed six wild edible mushrooms to rats and observed the following (Adewusi et al., 1993). Chlorophyllum molybditis is a good source of crude protein (CP 31.4%) with excellent

digestibility and a protein efficiency ratio higher than that of casein (i.e. better than milk protein). As its local name in Yoruba 'a jegba'riwo orun" (eat and hear voices from heaven) implies, this mushroom probably has hallucinogenic effect comparable to 'LSD'. The rats on this mushroom diet ate voraciously, their movements were extremely wild and their actions aggressive. This phenomenon is not new in mushrooms, as hallucinogens such as Psilocin and Psilocybin have been identified in another mushroom.
Termitomyces striatus, another mushroom tested, proved to be very toxic in the raw state with hind-limb paralysis developing within 3 days and death of all the animals on this diet occurring within another 24 h. Heating the mushroom at 90oC for 8 h or prolonged storage at 60oC reduced the toxic factor considerably as all animals on these new diets survived the experimental period. This study underlines the fact that cooking is an important procedure in the utilization of mushrooms in order to destroy the heat - labile toxic components. Another interesting result concerns Tricholoma lobayensis. This mushroom probably contains a toxic factor, which seems to produce sterility in male rats. Male and female rats fed T. lobayensis for 10 days failed to reproduce even after mating for several weeks. When the male rats were replaced with the control rats, the female rats became pregnant but when control female rats were mated with test male rats, there was no pregnancy.

These results are very disturbing in view of the fact that mushrooms could be a veritable source of additional protein but the observations have emphasized the need for further research into the toxic factors as well as efficient processing methods for detoxification. The T. lobayensis compound producing sterility in male rats poses a challenge to us chemists and the pharmacists. We just may be able to develop the first male contraceptive from this chemical.

THE WORLD OF ELEMENTS: Mr. Vice-Chancellor, Sir, some fifteen years ago, I initiated a new line of research on the content of mineral elements in foodstuffs and their bioavailability. The importance of these minerals lies in their vital functions in the body. Iron is an important element in the diet of pregnant and nursing mothers, infants, convalescing patients and the elderly to prevent anaemia. Iron and copper are components of metalloenzyme complexes such as cytochrome oxidase, essential in the respiratory chain. Sodium, potassium, chlorine and phosphorus are vital in the regulation of acid - base balance and normal metabolism while Na, K, Mg and Mn ions function as enzyme activators. Magnesium, in addition, plays a fundamental role in most reactions involving phosphate (energy) transfer and is also believed to be essential in the structural stability of nucleic acids and intestinal absorption. Calcium, phosphorus and magnesium provide hardness and rigidity to bones and teeth while zinc is necessary for protein and nucleic acid synthesis, carbohydrate metabolism, proper biomembrane integrity, normal development, pregnancy and delivery. Without the 4 % constituent in the body, there probably would be no life. 'Food' that is meat or flesh probably supplies most of these elements in sufficient quantities but the question again is how much meat does the ordinary man in the street get to eat?

Our research in Akoko and Ijesha zones as well as Maradi in Niger Republic has shown that a lower protein content of the food accompanies an increase in food consumption. This means that the increase in food portions is simply an increase in the starchy components. What is the content of these important elements in legumes - the meat of the poor? Will the mineral content in the starchy foods and the legumes satisfy the "at risk" group of people? It is well known that meat and meat products stimulate mineral absorption in the intestinal lumen but what happens in the situation whereby the food is mainly plant based? There was a gross lack of information in this area with regards to Nigerian diets. Our research findings (Adewusi and Falade, 1996) showed that 200g of most legumes in Nigeria would supply the 10-15mg iron, which is the RDA if all the iron content of the legumes is available. Unfortunately only 9-29 % of the iron content of these legumes is available as determined by simulated (in vitro) digestion. This means that these legumes can only supply about 10-30 % of the minimum RDA. Zinc content was high especially in the legumes developed by IITA, Ibadan and 30-34 % was found to be available. The calcium content of the legumes was also high and its bioavailability average. Magnesium level and availability were both very high in the legumes. In the raw legumes, phytate seems to be the dominant antinutritional factor negatively affecting the availability of the above named elements with tannin contributing substantially to the inhibition. In the cooked form, the role seems reversed as tannin tends to predominate as the major antinutritional factor inhibiting mineral availability with phytate playing a supporting role.

MINERAL ELEMENT - FOOD COMPONENT INTERACTIONS: I have given some examples of this type of interaction earlier. Phytate, dietary fiber and tannin are components of plant food sources that inhibit mineral availability while meat, meat products, ascorbic acid as well as other organic acids stimulate mineral availability in vivo. Is there any interaction between cassava meal and mineral availability? Our research findings (Adewusi et al., 1999) showed that the content of organic acids increase with fermentation period and so is the mineral availability from amaranthus in a composite cassava-amaranthus meal. The longer the fermentation period (up to five days) the higher the mineral availability. This should give our processors an additional incentive to ferment cassava for 4-5 days before processing it further for sale.

THE DELICIOUS MEAL: Our forefathers (and mothers) were good Scientists and very knowledgeable in the culinary arts. They perfected the art of fermenting locust beans (Parkia biglobosa) and melon (Citrullus vulgaris) seeds as spices for food. We have moved away from this tradition towards the seasoning salts marketed under several trade names. The major component of these seasoning salts is monosodium glutamate, which admittedly is a meat tenderiser and gives good flavour to the food. Despite these attributes, some people hate these seasoning salts with a passion, preferring to go back to basics (iru and ogiri). My group investigated the interaction between monosodium glutamate and mineral elements. We approached this study from the hypothesis that glutamic acid as an amino acid would enhance mineral absorption but contrary to our expectation, glutamate in addition to its reported mild carcinogenicity inhibits mineral availability. There is no doubt that iru and ogiri contain a high crude protein and lipid content (>20 %) with sufficient quantities of fat-soluble vitamins A & E. In addition, these ingredients are expected to contribute to the mineral content of the meal. Both iru and ogiri as well as monosodium glutamate inhibit iron and zinc availability by apparently different mechanisms.

TO COMPLETE THE MEAL: In the developed nations of the world, there are several courses to a meal; from two to five or six, at the end of which there's always tea, coffee and a sniff of brandy. These beverages are rich in either phenolic acid (chlorogenic acid in coffee), monomeric flavonoids (herb teas, lime flowers, peppermint) or complex polyphenols (i.e. polymerisation products as in black tea and cocoa). All the beverages have been found to be potent inhibitors of iron absorption and they reduced Fe absorption in a dose dependent fashion from plant-foods. Beverages containing 20-50 mg total polyphenol per serving could reduce Fe absorption by 60-70 %, inhibition by black tea has been estimated at 75-79 %, cocoa at 71 %

and peppermint tea at 84 % (Hurrell et al., 1999). Addition of milk to the tea or coffee has been shown to have little or no effect on the inhibitory effect of these polyphenols on Fe absorption.

Mr. Vice-Chancellor, Sir, those who could afford a 4-6 course meal cannot be counted among the "at risk" group of people for they would have consumed "food" both fish and animal flesh. The beverages do not inhibit absorption of heme-iron from animal sources (but the non-heme iron of plants is inhibited). For these 'food eaters', consumption of polyphenol containing beverages (tea, coffee, cocoa, red wine) with their meals could serve as a useful strategy in reducing iron absorption in patients with Fe-overload disorder. Having considered the situation in the developed nations, what is the position in the developing countries and Nigeria in particular? Well, Nature has a way to compensate. After a meal of gari with vegetable soup, we occasionally take a fruit (whichever fruit is in season at that time). These fruits contain low levels of minerals but have a considerable amount of ascorbic acid as well as other organic acids - which enhance mineral absorption. The result of our analysis on some common fruit juices indicated that the orange juice contained the highest level of ascorbic acid (55 mg/L), followed by grape fruit (45 mg/L), lime (29.4 mg/L) and pineapple (12 mg/L). The highest total organic acid content was however found in lime with a pH of 2.1, grapefruit (pH 3.1), pineapple (pH 3.5) and orange (pH 4.0) respectively. Orange and grape juices generally enhance the availability of iron, magnesium, calcium and copper from both amaranthus vegetable and cowpea. Lime and pineapple juice enhance magnesium and calcium availability in both amaranthus vegetable and cowpea but have no effect or inhibited the availability of iron and copper. The case of zinc was interesting in that all juices enhanced its availability in amaranthus vegetable but had no effect or decreased availability in cowpea.

HEMOPOIETIC HERBS: Mr. Vice-Chancellor Sir, I cannot but mention this topic as the latest addition, from my M.Sc. student, to our wealth of knowledge in the area of mineral availability. Our forebears used herbs to cure different diseases and became adept in this field. The herbs used for anaemia include sorghum stalk, cocoa stem, bark and/or root and "sobo" drink (a decoction of H. sabdariffa flower). Our investigation on "poporo" (sorghum stalk), sobo and cocoa root has validated the claim that these herbs could indeed be used in the management of iron deficiency anaemia. Our forefathers may not understand science or supply scientific proof; they however had a wealth of knowledge and experience that could complement the modern day medical practice. The "jungle connection" must therefore not be allowed to break completely.

...AND EVER SHALL BE (CONCLUSION)

My father was a Muslim, but he believed in education so much that he sent all his children to the catholic schools as the "best in town" at that time. In the catholic primary school, I was taught very early to say my prayers at the beginning and end of each day and each event. And so I now say "Glory be to the Father, to the Son and to the Holy Spirit; as it was in the beginning, it is now and ever shall be, world without end, Amen." I started this lecture with "IN THE BEGINNING", appraised the situation NOW, and predicted the way of the future. Maize will continue to be maize, sorghum will always be sorghum, the name breadfruit will not change, acha will remain as acha while cassava as a name has come to stay. However, the properties and nutrients of each food item will continually be improved to meet future challenges. As analytical techniques improve, science will play a greater role in the production and quality of what we eat.

I thank the University for giving me the enabling environment to conduct the research reviewed in this lecture and hope conditions will

improve to give generations behind me, the same or even better opportunities. Nigerians can do as well, if not better than their compatriots elsewhere in the world. The government and the industry should encourage academics for there lays our path to progress and our future.

I wish to thank my colleagues who participated in the research efforts presented in this treatise. To my wife, children, friends and others whose patience I have tasked over the years, I say thank you and please continue to bear with me. To all you, good people, I say may God provide the means to eat food. Thank you for your attention and patience.

God bless.

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