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Great KWASU Students,
Ladies and Gentlemen.

1. Preamble

It is with a deep sense of humility and gratitude to the King of glory that I stand before you to present the 7th in the series of inaugural lectures of the Kwara State University. Seven is a unique number that symbolizes perfection, completeness, and wholeness. This number is of significance because before the seventh- day, the creation of the whole world was complete, and God has perfected His creative work. Seven is called the number of God and it also signifies blessing; for this, I am greatly honoured. I want to ascribe all glory to God for His goodness and faithfulness in my life. When I was on the wings of the storms, He rescued and sustained me with

His infinite mercies and unfailing love. He is the Alpha and Omega, the I am that I am who makes all things possible. It is not of my might or power but of the Lord who has been so kind and gracious. May His name forever be praised.

Vice-Chancellor, Sir, my career as an Animal Scientist is not by accident but as a result of my intimate relationship with my parents of blessed memory. As a young boy, I used to partake in all aspects of subsistence Agriculture, which was my parents' occupation. Then, my father used to advise us to be hard-working in pursuit of our academic goals in order not to continue in drudgery farming. It was a challenging experience. His advice was instrumental in my decision to pursue a degree in my profession. I was admitted to the University of Ibadan to study Agriculture in 1978. When the opportunity came to specialize in a field of study, I opted for Agricultural Biochemistry and Nutrition. My choice emanated from my keen interest in exploring and explaining the biochemical basis of nutrition, which gives a better understanding of livestock feeding. My interest in Nutritional Biochemistry encouraged me to pursue a Master's degree which was funded by the Zard Scholarship Award in Agriculture and subsequently, I obtained a Ph.D. in the same field in 1990 from the University of Ibadan. My doctoral research elucidated the effects of under-used tropical legume seeds on animal productivity. From the research work, we have developed a routine analytical scheme for some plant components, and it has expanded frontiers for the innovative use of legume isolates.

I began my university teaching career at the University of Ilorin in 1991 as a Lecturer II in the Department of Animal Production and rose to the rank of Senior Lecturer in 1995. At the University of Ilorin, I inspired several students, both at undergraduate and postgraduate levels. I supervised fourteen M.Sc. and Ph.D. students, many of whom today are in academic and administrative fields. I was among the research group that won Bio-fuel grant for Ethanol Production from Cassava, leading to improved indigenous technology for ethanol production.

I was appointed as a Professor at Kwara State University in May 2012. I wish to thank the pioneer Vice-Chancellor, Professor AbdulRasheed Na'Allah and the management for this opportunity. Following my assumption of duty at KWASU, I played an important role in the design, planning and execution of infrastructural facilities for livestock in the Teaching and Research Farm. I also worked with Professor F. Oluleye, the pioneer Provost of the College of Agriculture, along with my colleagues in the Department of Animal Production, Fisheries and Aquaculture, to ensure the growth of the livestock section. Under the immediate past Provost of the College, Professor O.M. Aliyu, we were able to change the narrative and record improvement. Several crates of eggs were produced and sold daily to the community. Also, I imparted many communities in Kwara state through community development outreach programmes undertaken in Grasscutter production among rural and suburban dwellers as well as rural poultry production. Recently, we conducted training on animal health regarding the use

of the herbal plant for the prevention and treatment of diseases in livestock among farmers. Obligation to perform community service is to achieve the mandate of KWASU as a University for community development. As a member of the Students' Disciplinary Committee, we have maintained KWASU's zero tolerance to indiscipline, drug abuse, cultism and examination misconduct.

Vice-Chancellor, Sir, when I considered the topic for this lecture, it is not surprising that I settled for the title: **"Feed is Good, Toxicants the Bane"**. The findings from my research in Animal Nutrition and Feed Toxicology establish the credibility of this paradoxical statement. My quest for new food and feed resources for safe and sustainable production of animal protein underscored the systematic assessment of the nutrient profiles of several alternative protein and energy sources that abound in the country and are capable of enhancing poultry and livestock productivity at the least cost. However, a number of these alternative feed sources are associated with noxious factors that have exerted baneful effects on animal feeding.

The phenomenon relating to harmful substances was recognized and appreciated in feed and water from the time of biblical healing of noxious water of the spring at Jericho by Prophet Elisha;… 'You can see that our city is in a good spot but the water from our spring is so bad that it even keeps our crops from growing' (2 Kings 2:19 CEV). Thus, the harmful water neither confers an asset for the good city nor its yield ability.

In a broader sense, a Yoruba proverb says, "*Kókóró kan ló beyín ajá jé*". The connotation is of a dog with a clean

set of teeth but has a blemish, which is a cause for genuine concern. In the context of this lecture, the proverbial expression used is in a figurative sense. It metaphorically means: a single odd that impairs the quality of a good feedstuff. The proverb provides the basis for the good/excellent value of feed not only as a suitable material for the nourishment of animals but also contains substances that produce adverse biological effects on animal production. I have been able to use various approaches to detoxify feedstuffs for improved feed safety, among others, to contribute to the effective utilization of feed resources for increased production of animal protein.

2. Introduction

Agriculture had been the mainstay of Nigeria's economy before the discovery of oil and gas, and it is still an essential source of livelihood for a large part of our population, employing nearly three-quarters of Nigerian adult workforce. Agriculture remains the vital sector for investment in Nigeria to diversify the economy from the oil sector. An integral part of agriculture is the livestock sector which is very important to the socio-economic development of the country. Farm animals turn feed into high-quality animal protein such as meat, milk and eggs which are essential for normal development and good health; providing income to farmers through the sales of animals and their products; raw materials for agro-industrial development and offering employment opportunities along with numerous animal production and processing value chains. Although its contribution to the GDP over the years is less than its potential, the

sector contributes 1.6% and 7.5% to national GDP and agricultural GDP, respectively (NBS, 2019).

The recent estimates indicate that the Nigerian national herd comprises 18.4 million cattle, 43.4 million sheep, 76 million goats, 7.1 million pigs and 180 million poultry (FMARD, 2017). The majority of the animals are raised in an extensive production system comprising smallholders and nomadic herders. The smaller percentage of animals raised in the intensive (modern) system is expanding, especially in the poultry sub-sector. Intensive poultry production has increased in some commercial farms exceeding one million birds in a single facility (Zartech Farm Report, 2018). Milk, meat and eggs total production amounts to 0.5 billion litres, 1.4 and 0.6 million tonnes per year, respectively (FAOSTAT, 2019). Yet, Nigeria has not been able to meet the demand for animal products by the rapidly growing human population.

Low consumption of animal protein is a dominant feature of most Nigerian diets. Protein intake is not enough due to food insecurity. The per capita consumption per year of animal source foods in Nigeria is 9 kg of meat and 8 litres of milk and 3.5 kg of eggs or 55 pieces (FMARD, 2017). The consumption level of meat and milk is lower than the continental averages that are 19kg and 14litres respectively (FAOSTAT, 2019). Insufficient consumption of animal protein often leads to under-nourishment and malnutrition. To effectively combat such malnutrition and undernourishment, 55g of animal protein per person per day or 20kg per year should be provided (FAO, 2019). According to this organization, the recommendation is achievable if 33kg

lean meat or 60kg eggs or 230kg milk or 45kg fish can be consumed annually. These sources have all the essential amino acids but in zones where all of them are not readily available, consumption of the others need to be scaled up.

The major problems of farm animal production, especially monogastric animals which are fast-growing and prolific, include high cost and scarcity of feed, low productivity, a weak livestock extension system, and disease outbreaks. The high cost of feed is due to the competition between man, industry and farm animals for conventional sources of cereals like maize, the predominant supplier of energy in animal feed and plant proteins such as soybean, a supreme source of protein. These sources are in short supply, thereby making livestock farmers unable to purchase the quantity of feed needed for efficient livestock production. As such, the production of animal source food is affected. It is therefore necessary to search for substitutes/alternatives, and test the substitutes both in the laboratory for biochemical constituents and in the field for efficiency of their utilization by the animals. This is in line with the national livestock transformation plan as a sustainable approach for the production of animal protein.

3. Why Feed?

Feed, also called animal feed, is the material that, after ingestion is capable of being digested, absorbed and utilized for maintenance, good health and production. The feed from an Animal Scientist's perspective is a material grown or developed and given to animals, while the animals ultimately become food for man. Thus,

animal feed is a critical component of the integrated food chain. Feeds are complex substances that contain many chemical compounds, more than 50 of which are required to nourish the animal body. No feed is nutritionally complete and balanced to meet the needs of a given animal. A good feed provides nutrition for life, energy for work and ensures affordable, safe and sustainable animal protein. The compounds present in a feed capable of being utilized by animals to meet the basic needs and productive functions are known as nutrients. The classification of the nutrients falls into two groups: macro-nutrients (also called energy-producing nutrients) and micro-nutrients. Macro-nutrients are needed in relatively large quantities and include carbohydrates, fats and proteins. Micro-nutrients on the other hand are required in relatively smaller amounts and they include vitamins and minerals which are essential for the body. Figure 1 shows the main feed components. The different groups are beneficial and serve specific purposes in maintaining animal health, weight, and product viability.

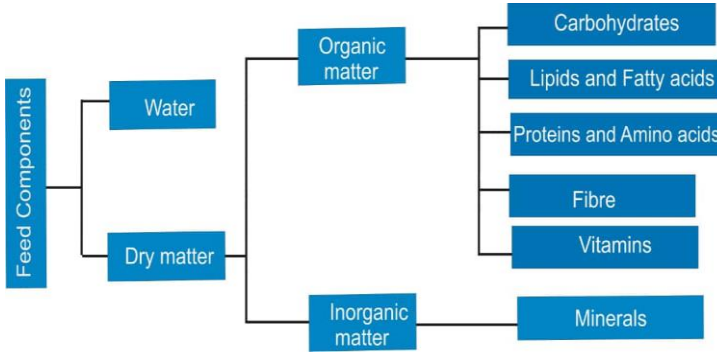


Fig. 1. The Main components of a Feed

Feed is the most critical element of animal production irrespective of species and livestock farming system. It is the element that attracts the highest cost. In commercial livestock production, especially in monogastric animals, feed contributes up to 70% of the total production cost, and the availability of low-priced, high quality feeds remain crucial for livestock and poultry production. Feeds in the Nigerian market vary widely in quality profile. The little standard obtainable in the industry is due to self-regulation which is imposed by the established operators.

In Nigeria, modern feed manufacturing geared strictly towards profitability began over fifty years ago. The industry which developed from small feed mills is now a large commercial enterprise. Commercial feed millers in the country include: Livestock Feeds Plc. Animal Care, Top Feeds, Olam Feeds and Ricogado Feeds. Feeds are scientifically produced by carefully selecting and blending the ingredients available as presented in Table 1. The primary ingredients used in animal feeds are energy and protein feedstuffs, supplemented with vitamins and minerals. No feed group is necessarily more important than the other, but many livestock farmers concern themselves the most with protein-rich feeds as they tend to be the most expensive feed to acquire. Several feed ingredients are generally used to create finished feeds for broilers, laying hens, pigs, dairy cattle, or fish. Farmers' demand for finished compound feed is mostly for broilers, layers and fish.

The availability and cost of feed ingredients are extremely dynamic in the market. Feed formulation

Table 1. Feed Ingredients Available for Production of Animal Feeds in Nigeria

Class	Ingredients	MO%	CP%	ME	EE %	CF %	Lysine%	Meth%	Ca %	P %
Energy	Maize	12	7.0	3150	3.0	3.0	0.2	0.15	0.02	0.27
	GC	10	8.0	3300	3.0	5.0	0.21	0.16	0.04	0.32
	Palm oil	-	-	7710	-	-	-	-	-	-
	Soya oil	-	-	8370	-	-	-	-	-	-
	Fish oil	1	-	7800	97	-	-	-	-	-
	Molasses	25	3.0	2343	0.1	0	-	-	-	-
Protein	SBM	10	42	2500	4.5	6.5	2.8	0.59	0.20	0.60
	FFST	8.0	37	3000	17.0	5.5	2.25	0.49	0.20	0.50
	GNC	10	40	2640	6.0	8.0	1.60	0.48	0.20	0.20
	CSC	9	35	2146	4.50	10.0	1.15	0.40	0.25	0.30
	RSC	12	29	2500	6.0	17.0	1.60	0.45	0.45	-
	Fish meal	8	72	2900	8.0	1.0	4.50	1.92	6.00	3.00
	BM	11	80	3220	1.0	1.0	6.90	1.00	0.28	0.22
Fillers/Ibr	Maize offals	9.0	9.0	2500	2.8	12.0	0.25	0.18	0.01	0.09
	Sorghum offals	9	9.0	2700	5.0	6.0	0.25	0.18	0.01	0.09
	Wheat offals	11	15	1870	3.50	8.50	0.90	0.25	0.10	0.30
	PKC	10	16	2450	7.50	15.0	0.64	0.39	0.21	0.16
	Rice bran	10	12	2860	25.0	9.0	0.50	0.24	0.04	0.46
	BDG	10	18	1980	5.0	15.0	0.90	0.40	0.20	0.16
	Corn cobs	11	2.3	528	0.40	35.0	-	-	0.11	-
Micro Ingre	Meth							100		
	Lysine						94.0			
Macro minerals	Bone meal								35.00	15
	Oyster shell								35.00	
	Periwinkle shell								32.00	
	Limestone								35.00	
	Salt									

Source: NIAS (2014). MO: Moisture, CP: Crude protein: ME: Metabolizable energy (kcal/kg), EE: Ether extract, CF: Crude fibre, Meth: Methionine, Ca: Calcium, P: Phosphorus, CSC: Cottonseed meal, RSC: Roselle seed cake, Ibr: Industrial by-products, PKC: Palm kernel cake, BDG: Brewer Dried Grains, Micro Ingre: Micro ingredients, FFST: Fullfat soya-roasted, GNC: Groundnut cake, BM: Blood meal, SBM: Soybean meal

constantly changes in response to prevailing conditions. The nutritionists endeavour to cut down costs without lowering productive performance and product quality and therefore, ingredients are combined in different

proportions to meet the different requirements of animals for micro and macro nutrients. Knowledge of the nutritional value of feedstuff is useful for the feed formulator to vacillate between feedstuffs and make-wise choices. The efficiency of utilization of the feed, which is the amount of feed required to produce a unit of product as meat or egg is the index of a suitable feed formulation. The least cost formulation is designed to be economical; still, it may not necessarily be the best formulation in a given set of circumstances.

Formulated compound feed is designed to increase growth rate and feed conversion efficiencies leading to an increase in the quality of animal products. This formulated feed has led to the reliance on a wide range of conventional feed streams destined for human consumption. Nigeria's feed production has advanced in global feed ranking as it moved from the 51st position (2.28 MT) in 2014 to 40th position (3.8MT) in 2015 (AGFS, 2016). Despite the increased production, Nigeria still has a deficit of 122.87kg/head of population in feed production (Robert, 2016).

In Nigeria, the increasing demand for animal protein coupled with the dwindling availability of conventional feed raw materials, call for changes in the current feed resources utilization. Many poultry farmers produce feeds to serve the farms, but the raw materials available to them are either expensive or difficult to get. It is imperative, therefore, to exploit the use of locally available feed resources which are not directly utilizable by man. Harnessing such a variety of feed sources for the development of suitable alternatives is very important in livestock production to mitigate the perennial problem of

the rising cost of feeding and safeguard stalling the feed industry.

However, available alternatives such as castor seed meal, shea nut cake, mango seed meal, moringa seed meal, cassava peel, among others possess noxious factors of biological origin. These factors reduce the utilization of nutrients and render the feed unsafe for animals. Efficient use of potentially utilizable nutrients is paramount for the production of animal protein.

In ruminant animal production, there have been increasing incidents of pastoral herdsmen and crop farmers' conflict due to inadequate pasture resources and clean water for grazing cattle in their immediate environment. The southward movement of pastoralists for grazing pasture has led to increased conflict with local communities. The conflict has resulted in the loss of lives and properties, as well as destruction of livelihoods and reduction in the production of beef and hides.

4. Anti-Nutritional Factors Affecting Animal Productivity

Vice-Chancellor, Sir, I mentioned earlier that feedstuff is the carrier of nutrients that are essential for sustenance and driving the productivity of animals. However, the increasing food demand by humans from limited conventional feed resources has dictated rearing of livestock and poultry on novel or unconventional feed sources. Often, these feeds contain one or more endogenous anti-nutritional factors. By definition, anti-nutritional factors (ANFs) are the chemical compounds synthesized in natural foods and feedstuffs by the normal metabolism of the plant species, which interfere with the

efficiency of digestion and utilization of the feed, precipitate many detrimental impacts on performance, health and productivity of the animal. The ANFs residues can contaminate and reduce the quality of animal products and pose risks to consumers. The deleterious substances are also referred to as natural toxicants, anti-nutrients, or secondary plant metabolites and are involved in the plant mechanism of defence against attack by insects and pathogens.

The ANFs are the most significant factor limiting the utilization of many tropical seed plants as animal feeds (Kumar, 1992). Indeed, the compounds exacerbate feed security and nutrition. Table 2 presents typical concentrations of ANFs in different plant sources. Exposures to these undesirable substances occur through the quest by animals for feed to meet their nutrient requirements. Figure 2 shows the common ANFs in feed sources and a brief overview of their effects upon ingestion by animals. The adverse effects range from growth depression and other undesirable physiological and biochemical alterations by hemagglutinins, through protease inhibitors-induced pancreatic hypertrophy, inhibition of proteolytic enzymes and phytate-induced iron deficiency (anaemia) as well as a decrease in egg and sperm production by gossypol and death by cyanogenic glycosides (Ologhobo, 2012). Although these responses are related to specific ANFs, a combined effect may be elicited in animals consuming feedstuffs endowed with multiple ANFs due to additive or

Table 2. Typical Concentrations of Selected Anti-Nutritional Factors in Different Plant Sources.

Toxicants	Principal Sources	Typical Concentrations
Lectins	Jack bean	73units/mg protein
	Winged bean	40-320 units/mg
	Lima bean	59units/mg protein
Trypsin inhibitors	Soybean	88units/mg
Cyanogens	Cassava root	186mg HCN/kg
Condensed tannins	*Accacia spp*	65g/kg
	Shea nut meal	98.7-156.4g/kg
Quinolizidine alkaloids	Lupin	10-20g/kg
Glucosinolates	Rapeseed	100mmol/kg
Gossypol	Cottonseed	0.6-12g/kg(free)
Saponins	Shea nut cake	30g/kg
Mimosine	*Leucaena leucocephala*	145g/kg (seed) 25g/kg (leaf)

Adapted from Annongu *et al.*, (1996); D'Mello (2000).

synergistic interactions between the groups of compounds.

The biological impacts of the ANFs are substantially contingent on the digestive system of the animal. From this point of view, these compounds have significant effects on monogastric animals but have less impact on ruminants as microbial fermentation in the rumen can break down some toxic compounds (Ramteke *et al*., 2019). Different animal species and ages react in



Figure 2. Major anti-nutritional factors or natural toxicants in feed sources and their effects on animals

different ways to the presence of toxicants in feeding materials which can vary from a low to a high level.

Many of the compounds in their raw forms are known to inhibit the production model predicted from the chemical composition of the feed, even when it is nutritionally adequate (Tadelle, 2015).

The mechanisms of action of natural toxicants occur through a variety of processes. At the general level, these compounds produce their adverse effects by interfering with physiological and biochemical processes. Some interfere with the digestive process to inhibit digestive enzymes; impede metabolic utilization of nutrients, or bind with minerals. The toxic effect depicted by feed bone toxicants is dependent upon the concentration. Also, nutrient interaction with the ANFs can determine the toxicity level. However, ANFs might not always be harmful even though it lacks nutritive value. Some may exert beneficial effects at low concentrations such as saponins, tannins and phytic acid.

The ANFs are classified based on their chemical structure, functions in animal or biosynthetic origin. Practical use of feedstuffs simply separates ANFs based on sensitivity to temperature into two major groups: heat-labile, comprising protease inhibitors, lectins and cyanogens, which are destroyed by standard processing temperatures, and heat-stable, which are not readily subject to destruction by heat processing such as polyphenolic compounds (condensed tannins), alkaloids, gossypol, saponins and the non-protein amino acids (canavanine, mimosine and β-ODAP). More often than not, a single plant may contain two or more toxic compounds, generally drawn from the two categories, which add to the difficulties of detoxification.

Proper processing of the feed sources by using appropriate technology is essential to remove the toxic components for the prevention of health hazards. Such an approach will increase farmers' access to healthy feedstuffs for profitable use.

4.1 Cyanogenic Glycosides

The cyanogenic glycosides are products of secondary metabolism. These compounds are composed of an α-hydroxy nitrile type aglycone and a sugar moiety. The cassava plant is known to store high level of cyanogenic glycosides in its tubers. The tuber is an important source of energy for human and livestock feeding. There are three distinct glycosides: Linamarin, found in legumes and cassava; dhurin which is present in immature grasses, and amygdalin present in almonds. Cyanogens can be hydrolysed by enzymes that are found in the cytosol to release HCN, which is a volatile gas. Cyanogenic glycosides occur in the vacuole of the plant cell. Damages to the plant result in the catabolic enzymes and glycosides coming together to produce HCN.

Ruminants are more susceptible to cyanide toxicity than pigs since the enzymes required for the release of HCN are destroyed in pigs by gastric HCl (Ramteke *et al*., 2019). The HCN is absorbed and rapidly detoxified in the liver by the enzyme rhodanase, which converts HCN to thiocyanate (SCN). Excess cyanide ion inhibits the cytochrome oxidase. Thus, it prevents ATP formation, and the tissues suffer energy deprivation leading to death (Kumar, 1992). Other effects include growth reduction and poor feed efficiency in animals.

Post-harvest wilting and drying of cyanogenic plants may decrease the impact of cyanide toxicity.

4.2 Protease Inhibitors

Protease inhibitors (PIs) are distributed widely within the plant kingdom, including the seeds legumes and cereals (Table 2). They are the most commonly encountered ANF factor of plant origin. There are two types of protease enzyme inhibitors: Kunitz inhibitor, which inhibits only trypsin, and Bowman-Birk inhibitor that inhibits trypsin and chymotrypsin. The PIs have the highest nutritional significance of any of the enzyme inhibitors found in legume feeds (Jamroz and Kubizna, 2007). They are known to prevent the digestion and utilization of protein and activate pancreatic enlargement (hypertrophy) as this gland produces more enzymes to make up for the excreted loss. The lost enzymes, being rich in amino acids, further reduce the amino acid status leading to growth inhibition in animals (Chunmei *et al.*, 2010). PIs are proteinous in nature and so, can be inactivated through heating the feedstuff by cooking, autoclaving or roasting.

4.3 Hemagglutinins (Lectins)

The hemagglutinins are glycoproteins that bind to the intestinal mucosal, causing epithelial damage and interfering with the absorption of nutrients. In addition, they easily attach to the red blood cells to cause agglutination. Upon ingestion, hemagglutinins resist digestion to pancreatic juice and substantial quantities of the substance may be recovered from the faeces of animals. In feed sources, the lectins of interest are

concanavalin A and ricin. Concanavalin A is a component of the jack bean (Table 2), which enhances the shedding of brush border membranes and decreases villus length, thereby reducing surface area for absorption in the small intestine. Ricin occurs in castor bean seed and has caused toxicity in all classes of livestock. Due to the presence of ricin, defatted castor seed cake having a crude protein content of 35% is not useful as a livestock feed.

4.4 Saponins

Extract of the bitter leaf is by nature foamy. Saponins are the cause of the foam. They consist of: polar (carbohydrates) and nonpolar (aglycone) that are coupled in complex chains. The structural complexity of saponins results in some physical, chemical, and biological properties, which include sweetness and bitterness, foaming and emulsifying, haemolytic and antimicrobial properties (Habtamu & Ngussie, 2014).

Saponins occur in oilseeds such as shea nut cake, soybean and sunflower. In high concentrations, saponins depress growth, feed intake and absorption of nutrients (Samtiya *et al*., 2020). However, when used at a low level, saponins have reduced blood glucose and depicted natural antioxidant properties (Gemede & Ratta, 2012). Similarly, saponins reduce the uptake of cholesterol in the gut, thereby inducing the hypocholesterolemic effect (Soetan & Oyewole, 2009).

4.5 Tannins

Tannins are a group of polyphenolic compounds that are widely present in plants, especially in nutritionally important legumes, forages and agro-industrial by-products. They are heat-stable compounds with diverse structures that share abilities to bind and precipitate proteins. Hydrolysable tannins and condensed tannins are two different groups of these compounds. The two types differ in their nutritive and toxic effects. The condensed tannins have more profound digestibility-reducing effects than hydrolysable tannins, which cause varied toxic manifestations due to hydrolysis by acids, bases or enzymes. Tannins decrease protein digestibility in monogastric animals by either making protein unavailable or inhibiting digestive enzymes.

In ruminants, dietary condensed tannins impact beneficial effects because of strong protein affinity to the compounds which offer protection against excessive degradation in the rumen, thereby reducing nitrogen pollution, and lessening methane emission from rumen fermentation (Redondo *et al*., 2014). When used at a low level, tannins have been recognised as effective antioxidants (Huang *et al*., 2018). Physical and chemical techniques employed to counteract tannins in feed sources include processing, use of wood ash, activated charcoal, alkali treatment, electron beam irradiation and polyethylene-glycol as well as solid-state fermentation. However, each technique has its implications such as cost, labour and effects on essential nutrients in the feed.

4.6 Phytates

Phytate represents a complex class of naturally occurring polyphosphorylated inositol compounds and are the primary storage compound of phosphorus in a plant, accounting for up to 80% of the total phosphorus (Steiner *et al.,* 2007). The compound concentrates in plant seeds mainly in legumes and cereals are generally present in feed sources, high in crude fibre, especially in wheat-offal, palm kernel meal and brewer's dried grains.

Phytate reduces nutrient absorption and bio-availability through the formation of indigestible complexes with minerals and proteins (Ramteke *et al.,* 2019). Previous studies have shown that these complexes cannot be digested or absorbed in the intestinal tract of monogastric animals due to the absence of phytase enzyme (Iqbal *et al.,* 1994).

The baneful effects of several types of ANFs in feeds result in stunted growth in chicken (Figure 3), loss of weight and hair in goat (Figure 4). On the other hand, animals given good feeds void of ANFs are healthy (Figure 5)

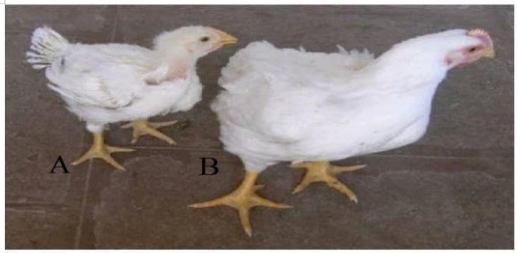


Figure 3 These broiler chickens are of the same age.
A. Note the small size, a result of antinutritional factors in the feed(*Prosopis africana* seed meal)
B. Note the big size, as feed does not contain antinutritional factor.



A. B.

Figure 4. Toxicity of *Leucaena leucocepala* in a goat

A. Fresh leaves and pods of *L. leucocepala*

B. Note the emaciation and complete alopecia in goat as a result of mimosine ingestion from the feed for 4 months.



Figure 5 . Goat is healthy when given forages void of antinutritional factors

5. My Contributions

Vice-Chancellor, Sir, my research focus has been on the chemical constituents involving nutrient profiles and antinutritional factors in feeds as well as the dietary effects of these naturally occurring toxicants on the health and productivity of farm animals. My research elucidated and resolved one problem or the other within and outside feed resources utilization by livestock and fish to provide sufficient animal and fish proteins for

human consumption. My contributions centre on the following principal areas:

1. chemical characterization of tropical feedstuffs;
2. effects of intrinsic toxic antinutritional factors in raw feed materials on animals;
3. improving the nutritional value of feed sources through processing techniques;
4. upgrading unconventional feed sources and agro-industrial by-products to useful animal feeds by solid-state fermentation;
5. antibiotics resistance in poultry;
6. application of probiotics as an alternative to antibiotic growth promoters in feeds; and
7. lipids from plant and animal sources as alternatives to fish oil in fish feeds.

5.1 Chemical Characterization of Tropical Feedstuffs

The dwindling availability of conventional feed resources has made it necessary to search for alternative protein and energy sources for feeding non-ruminant animals. In Nigeria, we have a wide range of alternatives with nutritional potentials but are underexploited. Information on the levels of nutrients in these alternatives is vital for effective utilization as livestock feed components. My research work started with the characterization of tropical legume feedstuffs with my supervisor and mentor, Professor Anthony Durojaiye Ologhobo, now deceased.

I investigated several under-used tropical legumes from different seed lines (Apata and Ologhobo, 1990, 1994; Apata, 2008), cassava and yam by-products (Apata

et al., 1999) for their protein and amino-acid profile, mineral content, carbohydrates and energy constituents.

The amino-acid composition of the legumes (Table 4) revealed the high content of lysine. Also, legumes are a rich source of protein. Of particular interest is the African yam bean which had 2.7 and 1.3 times higher Iysine content than groundnut and soybean meal, respectively. The high content of this amino acid in the legume could provide an alternative source of lysine to that of soybean in livestock feeds. Besides, these legume feeds consist of a high amount of valuable minerals. Some of the legumes are now being used to provide cheap and quality protein foods for humans and feeds for livestock. Rabbit growers are continually using our results by incorporating agro by-products into their rations.

Table 4. Amino acid composition of the protein of tropical legume feedstuffs (g/16 g N)

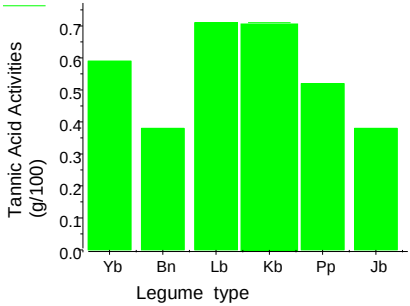
Amino acids (g/16 g N)	Bambara groundnut		Kidney bean		Lima bean		Pigeon pea		Jack bean	FAO/ WHO (1973)
	KAB-3	Oturkpo Local	Pondo-6	Yara-1	TPL 88	TPL 249	Ex-Ibadan	TUc55 37-1		
Essential										
Isoleucine	4.27	3.98	4.87	6.01	4.98	5.26	3.96	4.18	5.12	4.0
Leucine	7.82	7.59	8.63	8.38	8.71	8.37	8.04	7.43	9.07	7.0
Lysine	6.57	6.83	7.35	6.71	6.67	6.90	6.82	5.85	6.56	5.5
Methionine	1.38	1.29	1.19	1.32	1.38	1.24	1.37	1.42	1.47	
Cystine	1.51	1.40	1.06	1.18	1.05	0.98	1.24	1.06	0.89	3.5
Tyrosine	3.61	3.37	3.97	4.46	3.42	4.02	3.73	3.97	4.15	
Phenylalanine	5.69	5.25	5.75	5.26	7.31	6.46	8.62	8.11	5.97	6.0
Threonine	3.32	3.78	4.56	5.07	4.28	4.45	4.12	3.84	4.37	4.0
Tryptophan	1.31	1.19	1.44	1.12	1.21	1.03	0.86	0.94	1.02	1.0
Valine	5.13	4.81	6.15	5.94	5.59	6.10	0.47	5.23	5.85	5.0
Nonessential										
Aspartic acid	10.62	11.43	12.74	11.90	11.80	13.17	10.35	11.02	13.50	-
Glutamic acid	17.01	16.60	13.85	14.26	19.1	15.90	17.32	16.48	14.81	-
Alanine	4.29	4.74	4.37	4.61	4.98	6.20	6.17	5.45	4.95	-
Arginine	6.43	7.16	6.25	5.56	7.31	6.24	6.48	7.20	6.90	2.0
Glycine	3.64	3.82	5.11	4.26	6.10	5.13	4.15	3.86	4.63	-
Histidine	3.17	2.94	2.64	3.20	2.53	3.01	3.08	3.19	4.56	2.4
Proline	4.86	4.24	2.87	3.85	4.38	5.40	3.89	5.04	4.10	-
Serine	5.07	5.26	5.16	4.39	5.71	6.88	4.58	4.43	7.01	-

5.2 Effects of Intrinsic Toxic Antinutritional Factors in Raw Feed Materials on Animals

The presence of one or multiple harmful substances in feed sources prompted interest in this research, aimed at determining the levels of antinutritional factors in different legume feeds, roots, tubers and their by-products. Feeds of plant origin contain a variety of natural substances which cause: depression in animal growth, feed efficiency, nutrient digestibility and utilization; and produce undesirable physiological and biochemical alterations. The effects of these substances on the utilization of nutrients by animals and their role in deep-seated biochemical indices and tissue integrity were investigated (Apata and Ologhobo, 1989; Ologhobo, Apata and Oyejide, 1993; Ologhobo *et al*., 1993; Apata and Ologhobo, 1997; Apata and Babalola, 2012).

Protease inhibitors, tannins and phytates occur most widely in the tropical feeds (Figure 6) and were responsible for growth inhibition, undesirable haematological and serum biochemical alterations as well as mineral complexing. Heamagluttinins were less common except in kidney bean and jack bean (Figure 7).

Toxic cyanogenic glycosides were predominant in cassava and its by-products. In the practical use of this energy source, cyanide ion would cause cyanide toxicity. Our study on lima bean isolates was shown to cause abnormal changes in the structure of tissues when fed to broilers. Tissue slides showed hypertrophy of the pancreas, fatty-infiltration with multiple foci necrosis in the liver, glomerular congestion of the kidney, and alveolar septae thickening with pulmonary vessels congestion in the lung (Figures 8,9,10 & 11).



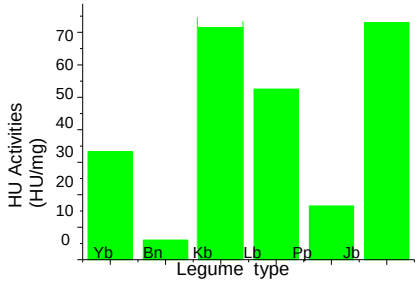


Figure7:Heamagglutinins activities in raw legumes

Figure 6: Tannins in raw legumes.

Jb= Jack bean; Kb= Kidney beans; Lb= Lima beans; Pp= Pigeon pea; Bn= Bambara groundnut; Yb= African yam beans.

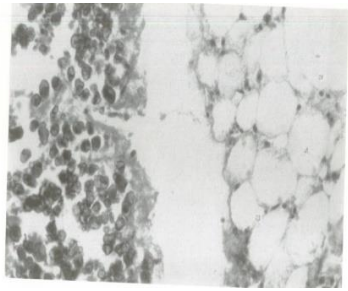


Figure 8: Section of the pancreas from chick fed 500gkg $^{-}$ Lima bean isolate showing hypertrophy. (H & E, x 250)

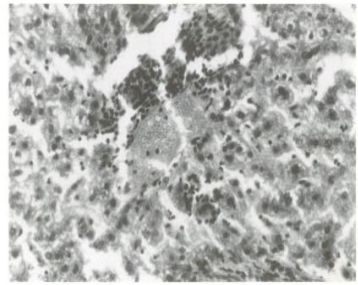


Figure 9: Section of the liver from chick fed 500gkg $^{-1}$ Lima bean isolate showing fatty infiltration with multiple foci necrosis (H & E. x 250).

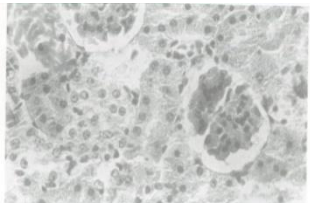


Figure 10: Section of the kidney from chick fed 500gkg $^{-1}$ Lima bean isolate showing glomerular congestion (H & E, x 400)

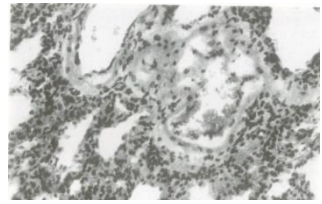


Figure 11: Section the lung fromm chick fed 500gkg $^{-1}$ Lima bean isolates showing congestion of pulmonary vessels and alveolar septae thickening (H & E, x 250)

5.3 Improving the Nutritional Value of the Feed Sources through Processing Techniques

Vice-Chancellor, Sir, an animal rejects a feed raw material due to offensive odour, spines, bitter taste and low palatability. Beside these limitations, the physical form of feedstuffs may be coarse or highly fibrous due to structural cell-wall components which may make the feeds unusable. Even if animals succeeded in consuming the feed, they will not be able to digest it due to antinutritional substances which exert toxic influences and structural components which impede accessibility to nutrients. So methods for removing or reducing the ANFs and/or degrading fibre to improve the quality of feed sources become imperative.

My research along this direction used different processing techniques which are: physical, chemical, or biochemical to detoxify and reduce ANFs to safe levels in several tropical feed legumes and other feed sources including jack bean, lima bean, kidney bean, castor seed cake, *Prosopis africana* seed meal, cottonseed meal and *thevetia* seed meal for poultry and pigs (Apata and Ologhobo, 1997; Apata, 1999, 2004, 2010, Oluwaniyi *et al.*, 2011). Enzymes and baker's yeast (*Saccharomyces cerevisiae*) were used to improve feed conversion ratio and nutrient digestibility of castor seed meal and cowpea testa, respectively in chicken (Apata and Ojo, 2000; Apata *et al*., 2001; Babalola, Apata and Atteh, 2006). Many livestock farms have adopted these methods in processing feedstuffs for effective utilization as animal feed ingredients (Figure 12 and Table 5).

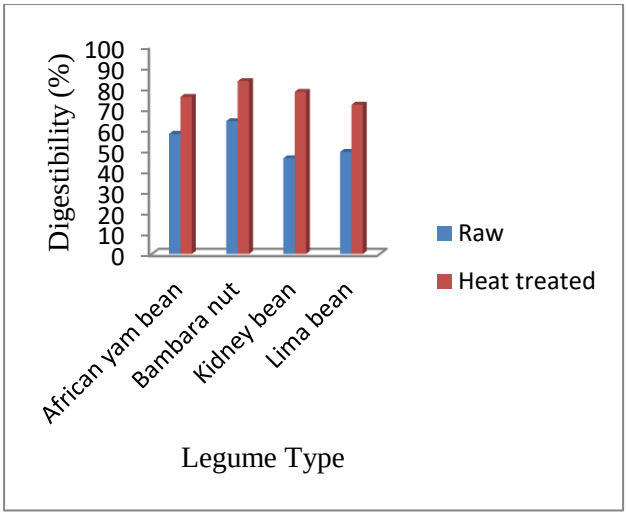


Figure 12. Effect of heat treatment on digestibility of animal fed legume-based diets

Table 5: *Effect of β-xylanase (βX) supplementation of boiled castor seed meal (BCSM) on pullet chicks*

	FI	WG	F:G ratio	FT T(h)	ANA (%)	AFA (%)
BCSM (gkg^{-1}						
0	52.9[a]	15.4[a]	3.5[a]	2.2[c]	83.1[c]	46.2[a]
100	61.8[b]	12.8[ab]	5.0[b]	2.0[d]	81.8[d]	39.5[b]
150	57.9[ab]	11.3[ab]	5.6[b]	1.8[c]	80.7[c]	35.8[b]
200	51.4[a]	10.4[b]	5.2[b]	1.7[b]	73.0[b]	30.1[c]
250	51.2[a]	9.1[b]	5.9[b]	1.4[a]	66.8[a]	28.7[c]
βX (gkg^{-1})						
0	53.8	10.9	5.5	1.7[a]	80.1[a]	35.2[a]
0.1	56.3	12.7	4.6	2.0[b]	81.7[b]	38.6[b]
BCSM x Bx	NS	NS	NS	NS	NS	NS

Values in the column with the same letter do not differ significantly at $p < 0.05$. NS= not significant. FI: Feed intake (g per chick day^{-1}), G: Weight gain (g per chick day^{-1}), F: G ratio: Feed gain ratio, FTT: Feed transit time, ANA: Apparent nitrogen consumption, AFA: Apparent fibre absorption.

5.4 Upgrading Unconventional Feed Sources and Agro-Industrial By-products to Useful Animal Feeds by Solid-State Fermentation

Solid-State Fermentation (SSF) or aerobic microbial transformation of solid materials is the growth of microbes on a solid medium in the absence or near-absence of the free-flowing aqueous phase. It is a process by which natural solid substrates are decomposed by known mono or mixed cultures of micro-organisms under controlled environmental conditions to produce high-quality animal feedstuffs. This transformation process is important in anaerobic conditions when there is no oxidative phosphorylation to produce ATP during glycolysis. The technology is useful for bio-transformation and bio-detoxification of agro-industrial by-products and wastes to forms that are utilizable as feeds for animals.

Simple stomach animals have reduced capacity to utilize certain feedstuffs, particularly those with high fibre and elicit an antinutritional effect. My research work in this category used SSF by *Aspergillus niger* and *Rhizopus oligosporous* to degrade fibre and reduce the endogenous ANFs in feed sources for monogastrics (Apata, 2010; Apata and Atteh, 2016). Using SSF, we have upgraded the nutritional characteristics of many unconventional feed resources including *Terminalia catappa* fruit meal by reducing tannins and crude fibre levels to 59% and 50%, respectively; causing a positive influence on productive performance, nutrient retention and intestinal morphology. The fermented meal could replace 40% part of maize in animal feeds, leading to a reduced cost of production.

5.5 Antibiotic Resistance in Poultry

In poultry and livestock management, antibiotic resistance (AR) occurs when bacteria develop the ability to survive exposure to antibiotics (also known as antimicrobial drugs) designed to kill them or stop their growth. The intensive management practices in farm animals depend a lot on the use of antibiotics for therapeutic and prophylactic purposes, as well as antibiotic growth promoters (AGP) which promote AR. This is accelerated by the misuse and overuse of antibiotics, and/ or poor infection prevention and control. My efforts have been on enhancing the utilisation of feeds containing anti-nutrients which is a nutritional input in livestock farming. AR is a significant problem in the utilisation of nutrients in animal production and the safety of the derivable products. Additionally, the development of AR in a bacterial population affects livestock health management in hard to treat diseases and can cause an increase in the cost of production, high morbidity and mortality. It is also an emerging public health issue for society because of the possibility of transferring zoonotic AR bacteria to humans.

The interest in reducing the risk of getting antibiotic resistance infections in animal husbandry necessitated critical reviews (Apata, 2009, 2012). These provide insights into the sources of antibiotics, incidence and development of antibiotics resistance in poultry, public health implications, and strategies for containment as well as the probiotic application as an alternative approach to sub-therapeutic antibiotic usage in poultry (Figure 13). Improvement in the hygienic practice of handling raw animal products and adequate heat

treatment are steps that can be taken to reduce the impact and limit the spread of bacteria resistance to humans.

A study by Adesina, Opasola, Apata and Alli (2018) evaluated the prevalence and antibiotic resistance of *Salmonella* spp isolated from chicken eggs sold in Ilorin. *Salmonella* spp prevalence had 67% multi-drug resistance (MDR) to all antibiotics used except gentamicin (Figure 14). A major finding from this study was a 100% resistance to cefuroxime (Figure 15), third-generation cephalosporin antibiotics used in the treatment of human bacterial infections. The observed MDR portends grave consequence in public health care provision against *Salmonella* infection in humans involving an antibiotic-resistant strain of animal origin.

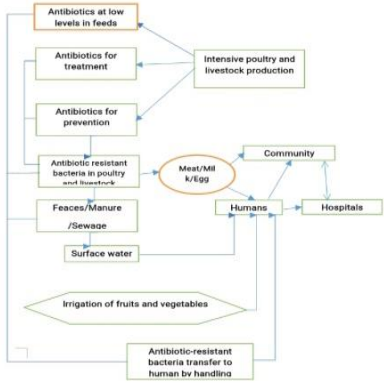


Figure 13. Sources of Antibiotics and Various Routes for the Transmission of Antibiotic Resistance from animals to humans.

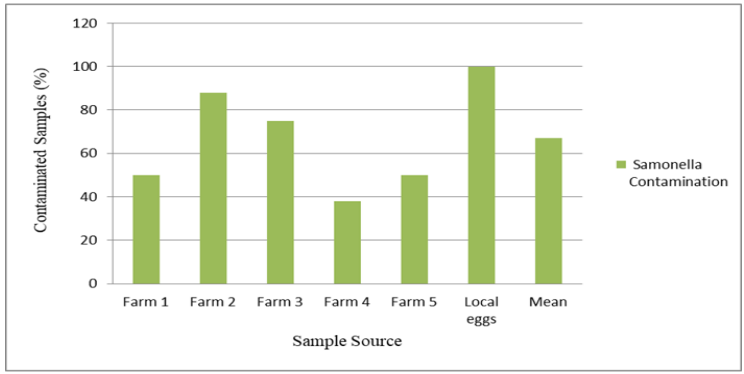
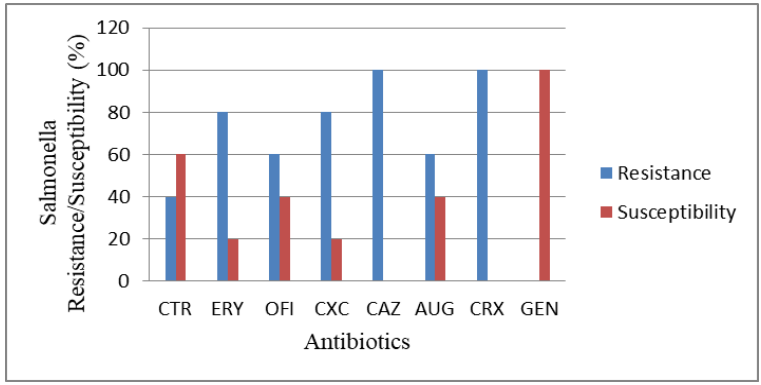


Figure 14. Prevalence of *Salmonella* contamination in Eggs collected from different farms in Ilorin metropolis



CAZ) ceftazidime (30µg), (CRX) cefuroxime (30µg), (CTR) Ceftriaxone (30µg), (ERY) Erythromycin (5µg), (CXC) Cloxacillin (5µg), (AUG) Augmentin (30µg), (GEN) Gentamycin (10µg), and (OFI) Ofloxacin (5µg)

Figure 15. Antimicrobial resistance of salmonella to some tested antibiotics

5.6 Application of Probiotics as an Alternative to Antibiotic Growth Promoters in Feeds

Vice-Chancellor, Sir, the impact of continuous use of antibiotics as antibiotic growth promoters (AGP) and for prevention and treatment of diseases led to the prevalence of antibiotic-resistant bacterial strains. Such practices have also raised concern about the possible build-up of antibiotic residues in products, which can be harmful to consumers. The risk of getting antibiotic-resistant infections in an intensive production system is high. Finding alternatives to AGP is a worldwide priority.

My quest for alternatives to AGP has resulted in the discovery of probiotics or direct-fed microbial. Probiotics, are mono or defined mixed cultures of live micro-organisms which, when applied to animals, can benefit the host by improving its intestinal balance. Probiotic bacteria mainly used are the lactic acid bacteria such as Lactobacilli and Bifidobacteria which are found in large numbers in the gut of healthy animals. Probiotics play a vital role in disease prevention. They enhance growth performance, non-pathogenic, produce safe edible products and do not carry antibiotic-resistant markers.

I conducted some research works on probiotics, aimed at *in-vitro* evaluation of a culture of *Lactobacillus bulgaricus* (LB) as an alternative to in-feed antibiotics for meat-type chicken, focusing on growth performance, nutrient digestibility and immune response (Apata, 2008; Ogundere *et al.*, 2010). The findings revealed similar performance of chickens on LB and antibiotic diets. Dietary consumption of the LB at 60mgkg-1 improved

weight gain by 11% in broiler chickens compared to the control group. A major discovery was the presence of a curvilinear stimulatory effect on systemic immunity upon ingestion of LB (Figure 16). The immune stimulation elucidated an underlying mechanism for LB probiosis to accomplish its putative beneficial effects. My effort to ascertain the optimum antibody production in broiler chicks fed different LB levels earned me membership in the American Chemical Society.

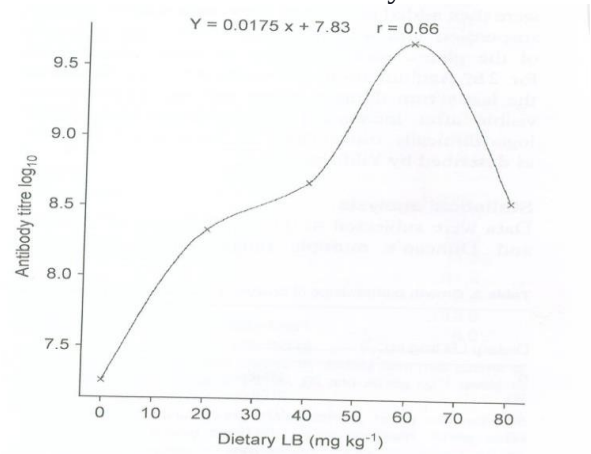


Figure 16. Antibody production in broiler chicks fed different *Lactobacillus bulgaricus* (LB) levels.

5.7 Lipids from Plant and Animal Sources as Alternatives to Fish Oil in Fish Feed

Fish farming is an important source of income but the high cost of fish oil and fish meal, which are the main lipid and protein sources in fish feeds, has hindered the sector from realizing its full potential. The rising price of fish oil and the unsustainability of this resource prompted

research interest conducted in a group with my students to find economically viable and environmentally sustainable alternative lipid sources in fish feeds. The goal is to utilize less expensive sources of oils as alternatives to fish oil. The fish oil contains highly unsaturated fatty acids: eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). To achieve this, we investigated less costly and readily available plant and animal sources of oil as alternatives to expensive fish oil for culturable African catfish (*Heterobronchus longifilis*). This fish is cultured primarily in freshwater ponds because of its unique qualities of hardiness, rapid growth and good market potential (Babalola and Apata, 2006). The experiments covered three fronts:

(i) Fatty acid composition and quality of lipids from plant and animal sources

Babalola and Apata (2011) investigated some alternative lipid sources for their chemical properties and quality. We found that soybean and sunflower oils contain high iodine value and are rich sources of polyunsaturated fatty acids which can help reduce low-density lipoprotein (LDL), bad cholesterol. Low thiobarbituric acid reactive substance (TBARS) values in palm kernel oil; palm oil and soybean oil revealed the occurrence of the protective action of natural antioxidants in the oils. Fatty acid profile (Table 6) depicted an appreciable omega-3 and/or omega-6 fatty acids in palm oil and soybean oil which underscored their suitability as alternative lipid sources in supporting satisfactory growth and health of farmed fish. Apart from being an important energy source, these fatty acids are the precursors for the long-chain

Table 6. Fatty Acid Profile of Some Lipid Sources (g/100g total fatty acid)

Fatty acid	Molar %										
	FO	PKO	SNO	L	SO	PO	SFO	CO	GNO	CF	MSO
12:0	ND	54.45	ND	ND	0.14	0.18	ND	49.85	1.64	ND	0.02
14:0	9.10	14.61	ND	2.04	0.36	1.07	0.13	16.57	0.67	0.88	0.09
16:0	10.63	12.39	4.96	29.78	11.91	39.38	6.06	10.16	31.04	12.15	9.69
18:0	2.45	1.40	41.26	12.99	3.12	4.96	2.91	7.28	2.28	7.44	6.25
20:0	ND	ND	1.18	ND	0.09	0.27	0.25	ND	1.37	0.35	0.27
22:0	ND	ND	ND	ND	0.08	ND	ND	ND	3.08	ND	ND
16:1n-9	11.45	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.10
16:1n-7	ND	2.50	ND	ND	ND	0.11	0.12	0.25	ND	ND	ND
18:1n-9	11.81	12.09	46.55	45.23	23.58	43.93	21.65	4.18	19.81	30.95	32.56
18:1n-7	10.06	ND	ND	ND	ND	1.64	1.49	ND	ND	1.97	ND
20:1n-9	ND	ND	ND	ND	ND	ND	ND	ND	1.24	ND	0.15
22:1n-9	ND	ND	ND	ND	ND	ND	ND	ND	0.11	ND	0.21
18:2n-6	8.26	1.98	6.05	9.95	53.94	8.24	67.27	10.49	38.22	42.48	50.46
18:3n-6	9.07	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
20:3n-6	2.02	ND	ND	ND	ND	ND	ND	ND	ND	0.03	ND
20:4n-6	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.04	ND
22:4n-6	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01	ND
18:3n-3	5.03	0.57	ND	ND	6.78	0.22	0.10	ND	0.54	3.50	0.20
20:5n-3	9.39	ND	ND	ND	ND	ND	ND	ND	ND	0.15	ND
22:5n-3	1.73	ND	ND	ND	ND	ND	ND	ND	ND	0.04	ND
22:6n-3	8.99	ND	ND	ND	ND	ND	ND	0.30	ND	ND	ND
ΣSAT	22.18	82.85	47.40	44.81	15.70	45.76	9.35	83.82	40.08	20.82	16.32
ΣMUFA	33.32	14.59	46.55	45.23	23.58	45.57	23.14	4.43	21.16	32.95	33.02
ΣPUFA	44.50	2.55	6.05	9.95	60.72	8.46	67.37	10.79	38.76	46.06	50.66
ΣUNSAT	77.82	17.14	52.60	55.18	84.30	54.03	90.65	15.22	59.92	79.01	83.68
Σn-6	19.35	1.98	6.05	9.95	53.94	8.24	67.27	10.49	38.22	42.56	50.46
Σn-3	25.04	0.57	0.00	0.00	6.78	0.22	0.10	0.62	0.54	3.68	0.20
n-6/n-3	0.77	3.47	0.00	0.00	7.96	37.46	672.7	16.92	70.78	11.57	252.3
n-3/n-6	1.30	0.29	0.00	0.00	0.13	0.03	0.00	0.06	0.01	0.09	0.00

ND - not detected, FO- Fish oil, PKO- Palm kernel oil, SNO- Shea nut oil, L- Lard, SO- Soybean oil, PO- Palm oil, SFO- Sunflower oil, CO- Coconut oil, GNO- Groundnut oil, CF- Chicken fat, MSO- Melon seed oil, n-3- omega 3, n-6- omega 6.

polyunsaturated fatty acids for freshwater fish.

(ii) Tissue fatty acid modification in catfish by tropical vegetable oils

The inability of fish to synthesize long-chain poly-unsaturated fatty acids (PUFA) de novo, including essential fatty acids such as linoleic (18:2 n-6) and linolenic acid (18:3 n-3) prompted the investigation into the assessment of vegetable oils in the synthesis of PUFA in farmed fish (Babalola and Apata, 2012). PUFA plays a vital role in fish quality. Feeding catfish with diets containing vegetable oils as alternatives increased the weight and fillet omega-3 and omega-6 PUFA similar to fish fed fish oil. Our study revealed the ability of a tropical freshwater fish to elongate and desaturate 18-carbon fatty acids. There is a bio-conversion of linolenic acid to PUFA with 20-22 carbons of the n-3 series. These findings allow the production of fish feeds with less expensive vegetable oils and invariably reduce the cost of the feed. Also, the increasing level of n-3 long-chain PUFA with dietary palm oil and soybean oil modifies the fatty acid profile of the edible portion which confers a tremendous nutritional value for human health.

(iii) Impact of alternative oils on the liver and intestinal histology of fish

Many of the vegetable and animal oil sources evaluated as alternatives to fish oil are high in omega- 6 PUFA and can cause an imbalance in the dietary fatty acids and modify the functioning and morphology of the liver. Thus, the use of such raw materials prompted our

investigation into the impact of total dietary replacement of fish oil at 6% with the alternative sources, focusing on histological alterations in liver and intestine of young African catfish (Babalola *et al*., 2011). The findings showed that dietary lipids containing chicken fat, shea nut oil and lard induced accumulation of lipid in the livers of the fish. These diets affected the integrity of the hepatocytes (Figures 17-18). Whereas hepatocytes population in livers from the dietary fish oil, soybean oil and palm oil had moderate lipid deposition (Figure 19). Findings showed no apparent abnormalities in the epithelial cell of the intestinal section among different dietary lipids.

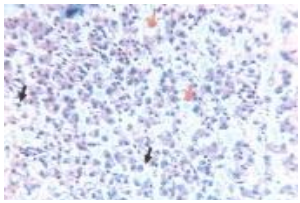
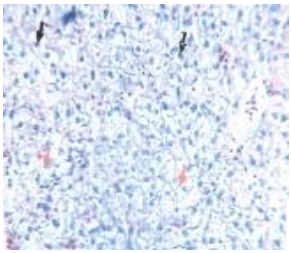
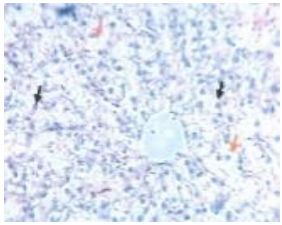


Figure 17: Liver of H. longifilis fed C F. Hepatocytes with nuclei located at the peripheral of the cell wall and severe lipid infiltraton (arrow) of the cytoplasm (H &E, bar = 50µm)

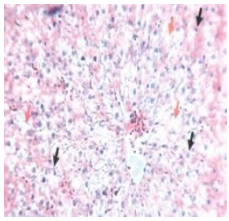


(a)

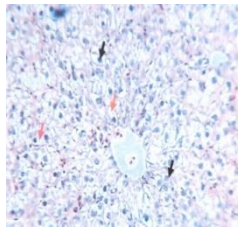


(b)

Figure 18. Liver of *H. longifilis* fed (a) SNO and (b) L showing hepatocytes with nuclei located at the peripheral of the cell wall and lipid vacoules in the cytoplasm (H& E, bar=50µm).



(a)



(b)

Figure 19. Liver of *H. longifilis* fed SO (a) & PO (b) showing hepatocytes with centrally located nuclei and moderate lipid vacuoles in the cytoplasm (H & E, bar = 50 µm).

Our researches on fish provide useful information in formulating cost-effective, practical feeds based on vegetable oils for catfish, which is a species of increasing interest in Nigeria.

6. Conclusions and Recommendations

Vice-Chancellor, Sir, ladies and gentlemen. I have in the course of this lecture highlighted the importance of animal feeds and endeavoured to give a comprehensive overview of feed natural toxicants that exert effects contrary to optimum nutrition. Considering that the quality and quantity of derivable animal products are directly related to feeding and nutrition, the quality of feedstuffs can be said to be a critical component that directly correlates with the production of animal protein, health and overall profitability in livestock farming. I have highlighted hindrances due to the presence of natural toxicants limiting the utilization of a broad spectrum of unconventional feed sources, as a significant challenge to feeding livestock in the country.

My research evidenced the nutritional characteristics of a broad range of tropical feed resources

and enumerated remedies and strategies to eliminate and/or reduce the baneful effects of natural toxicants on production efficiency, metabolism and healthiness of the animals. Feed safety contributes to feed and food security and decreases feed losses. My work also provided information on upgrading some unconventional feed sources by SSF to replace part of maize in animal feeds for reduced cost of feed production. In the area of antibiotic resistance, I observed multi-drug resistant to *Salmonella* spp. from eggs which portend grave consequences in public health care space.

On probiotics, my research has revealed that a culture of *Lactobacillus bulgaricus* could serve as an alternative to AGP in animal feeds. It also elucidated systemic immune stimulation as an underlying mechanism of action of *Lactobacillus bulgaricus* to accomplish its beneficial effects. We provided useful information regarding cost-effective fish feed production for African catfish using less expensive vegetable oils as alternatives to fish oil which is more costly and unsustainable.

Upon the foregoing findings, I wish to make the following recommendations:

1. *Development of Feed Safety Standards*

Safety standards should form a fundamental component of policy measure to support the feed industry. Such standards in respect of natural toxicants and contaminants in ingredients used for feed production should be developed for different species of animals. Operators in the industry have to comply with the safety limits and strictly implement NIAS feed regulations to

enable high level performance through the use of consistent quality feeds that ensure marketing of feeds to meet international standard.

Also, feed safety should be a vital part of the Animal Production curriculum to inculcate proper knowledge of undesirable substances in feeds, since the safety of animal-source foods begins with the safety of animal feeds.

2. *Equipment Design and Improved Collaborative Research*

Simple equipment for rapid detection of baneful substances should be produced to monitor and ensure feeding safe feedstuffs to livestock. To achieve this, engineers are challenged to design appropriate instruments in conjunction with nutritional biochemists to test for feed toxicants. Interdisciplinary researches should be encouraged to develop efficient and effective post-harvest detoxification procedures to remove the heat-stable ANFs in alternative feed ingredients for the realization of their full potentials by livestock farmers.

Presently, there are feedstuffs like moringa seed meal, soybean and other feed sources of interest in Nigeria. As such, there is a need for synergy among engineers, nutritionists and toxicologists to ensure that the existing commercial feed mills are equipped with detoxification facilities to ensure their effective treatment in alleviating inadequate feed supply.

3. *Provision of Security by the Government*

The farmer-herder conflict has become Nigeria's security challenge. Government should give assurance of adequate security to prevent crop farmers - herdsmen

conflict, kidnapping and banditry in order to ensure sufficient production of crops for feed manufacturing.

4. *Breeding of Low ANFs Crops*

While genetical improvement by plant breeders to achieve low ANFs in crops used as feeding materials like leguminous seeds, oilseeds, root and tubers are advocated, this should be done with caution. This is because low ANFs strains may be unproductive and of low vigour because of the involvement of some ANFs in the plant mechanism of defense against attack by insects and pathogens.

5. *Surveillance of Incautious Use of Antibiotics in Animal Production*

Imprudent use of antibiotics in animals which promotes the development of antibiotic-resistant bacteria in the production and value chain of animal products should be monitored by regulatory agencies like the National Agency for Food and Drug Control (NAFDAC) and NIAS, to avoid further selection and spread of AR bacteria.

6. *Promoting Livestock Farming*

The government needs to create a conducive environment so that more youths, graduates and rural women can take up various livestock farming opportunities, particularly poultry, pigs, rabbit, fish and other aspects of livestock production. This would not only create jobs, provide income, alleviate poverty and reduce restiveness but would also enhance the production of animal protein which is currently in short supply for our teeming population. This approach deserves a much higher place on the national agenda.

7. *Increased Private Investment in Feed Industry*

There is a need for increased private sector participation in the livestock feed industry to produce and market quality animal feeds. An increase in investment will enable the production of superior feed at competitive prices and stimulate the vast majority of the rural economy.

Vice-Chancellor, Sir, permit me to end this lecture by quoting from the Holy Scripture which says "…He cried out to the Lord, and the Lord showed him a tree. When Moses threw it into the water, the water became safe to drink…" (Exodus 15:25, NET). Given what has been said, a baneful feed could be turned valuable.

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