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Inaugural Lecture 125

ANIMAL FLUX AND ANIMAL PRODUCTS

By

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Professor of Animal Science

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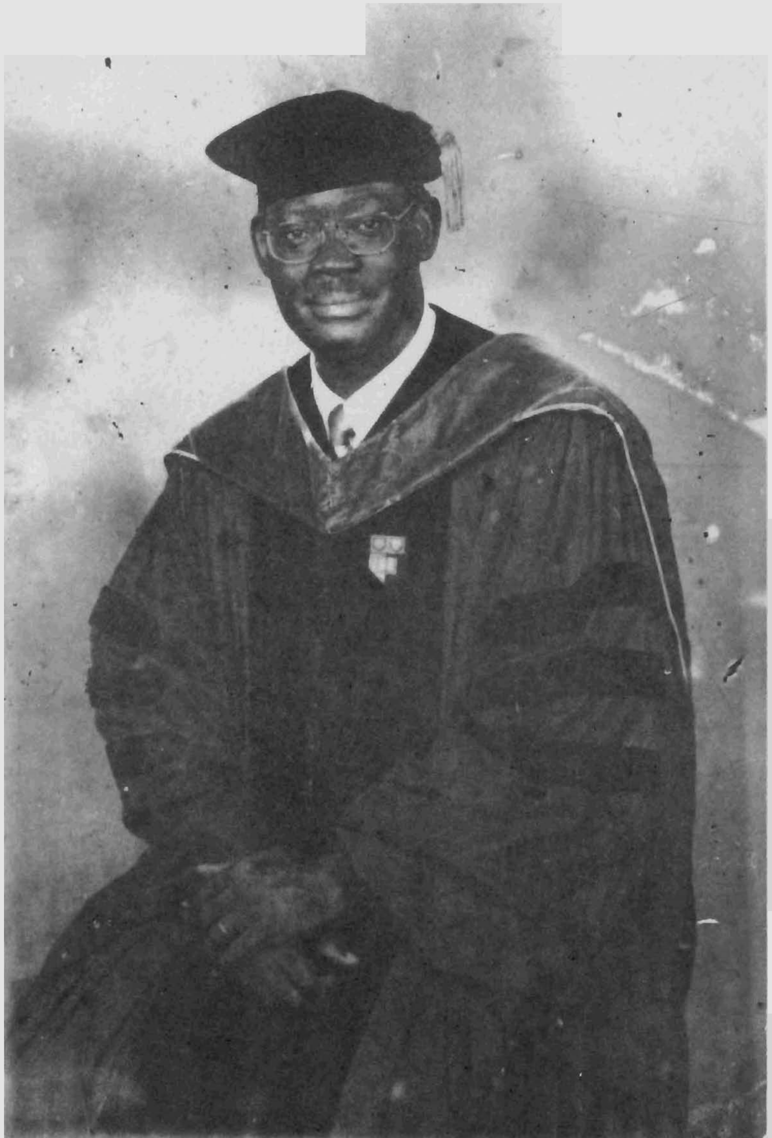

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INTRODUCTION

The production of food is a process of energy transformation - changing energy from an inedible into an edible form. Different foods vary in the energy required to make them fully edible. Energy use in food production has been increasing faster than its use in many other sectors of the world economy and has become an overriding factor in food production, distribution and consumption. Today, the source and use of energy are key issues in every area of human endeavour. Agriculture is unique because one of its major energy sources is the sun..

Energy Sources and Sinks

In our Solar system, the Sun is the ultimate material source of energy. As received on Earth, this energy is neither created nor destroyed but is transformed, for example, into wind movements over land and sea (Storms and Cyclones) and into waves of the ocean. These climatic/weather forms of energy are examples of renewable sources of energy which are all dependent on the sun. The certainty of the sun rising every day renews the supply of these renewable forms of energy on earth such as: solar, wind, tidal, water and biogas. Truly, the steadfast love of the Lord never ceases, His mercies never come to an end. They are new every morning. Great is His faithfulness (Lamentations 3:23, the Holy Bible).

There are instances when the transformation of the Sun's energy does not follow an orderly process or yield a predictable product but results in chaos, destruction and general disorderliness, randomness or positive entropy change. Cyclones, tempests, typhoons and wars demonstrate this on a large scale; floods, volcanic eruptions, mud slides and avalanches on a medium scale, while civil unrests, communal clashes and family feuds do so on a small scale. These events and situations act as sinks of energy and often yield unpredictable results. But there are other more useful energy sinks with far more desirable results. Plants and animals fall into this category of useful energy sinks.

Plants that have chlorophyll for trapping sunlight directly are the most common illustration of the concept of solar energy sinks. The conversion of CO_2 and H_2O into glucose and other carbohydrates is the basis of a series of food chains and energy cycles on earth. Living organisms illustrate the cycles of carbon and oxygen in the biosphere. There is a nutritional interdependence between living organisms in nature, exemplified by the carbon cycle, which occurs at many levels in the biosphere, and is characteristic of all ecological systems. The magnitude of the carbon cycle in the biosphere is enormous; it has been estimated to turn over 3.5 X 10^{11} tons of CO_2 annually. There is a massive flow of energy involved. Annually, some 4.2 X 10^{19} kilojoules of solar energy is used to convert CO_2 into biomass by photosynthetic organisms in the biosphere. This biological energy flow is twenty times greater than the flow of energy through all man-made machines on the face of the earth.

Agricultural Chemistry, which I have had the privilege of teaching for more than 20 years, traces the metabolic pathways of the solar energy-produced chemicals and their conversion into the other macromolecules and biomolecules that support and promote life. As green plants imbibe solar energy, they store surplus chemical energy in roots, tubers, stems, leaves and fruits which become food sources of energy and other nutrients for man and animals. In animal agriculture, we are concerned with the production of domesticated animals for food, fibre, draught power, games and sports. Of all these uses of domesticated animals, their use as food in the form of animal products is of paramount importance.

ENERGY FLUXES AND ANIMAL PRODUCTS

In the first textbook on animal products ever written to my knowledge (Sonaiya, 1984a), we describe animal products as: "the raw materials that are derived entirely or mainly from the body of animals or their carcasses". The main animal products are meat, milk and eggs. Each animal product is studied as an independent pure and applied discipline: Meat Science and Muscle Biology, Meat Technology; Dairy Science, Dairy Technology; Egg Science, Egg Technology. In many institutions, Meat Science and Technology will be found in the Department of Animal Science, Dairy Science and Technology in the Department of Dairy Science and Egg Science and Technology in the Department of Poultry Science. In some institutions, all three may be housed in the Department of Food Science and Technology. This explains the rarity of a textbook or even a course on Animal Products.

Here, at Obafemi Awolowo University, the study of animal products is shared unevenly between the Departments of Animal Science and Food Science and Technology. My promotion in 1992 to the grade of Professor marks the inauguration of the Chair of Animal Products in the Department of Animal Science.

When I was recruited in 1977 to pioneer this field in the Department of Animal Science, my background was in Animal Nutrition in which I was completing the Master of Philosophy degree. Hence, during my doctoral studies at Cornell University (1977-1980), I had no home-related priority to guide me. I finally decided to work on the effects of electrical stimulation on the carcasses of beef and sheep. In the 1970's, this was an area rich in historical perspectives and industrial application. It had been stated that, in 1749, Benjamin Franklin, the legendary American scientist and statesman, found that "Killing turkeys electrically, with the pleasant side effect that it made them uncommonly tender, was the first practical application found for electricity".

Electrical stimulation of meat carcasses involves the passage of electricity through the carcass at some point in the slaughtering and dressing process. Electrically induced contracture of the muscles of the carcass hastens the normal biochemical and physiological events occurring in muscle after death, i.e., depletion of energy stores, decline in muscle pH and the onset of rigor mortis. Within a few years of the reports from New Zealand suggesting that electrical stimulation prevented cold shortening, the practice spread to virtually every developed country. In Sweden, for example, more than 90% of the beef meat produced was electrically stimulated.

The reason for the great interest in electrical stimulation was the need to avoid cold and thaw shortenings, two quality-damaging phenomena occurring in meat that was not allowed to go into rigor mortis before it was refrigerated or frozen. Such meats become incredibly tough and virtually inedible, even for the African! Electrical stimulation of the animal carcass soon after slaughter has proved to be one way of hastening the development of rigor mortis and significantly reducing the time before meat can be frozen.

This seemingly esoteric piece of research had a salutary effect on my career development. Shortly after publishing our findings (Sonaiya and Stouffer, 1982; Sonaiya, Stouffer and Beerman, 1982) and presenting them at the International Congress of Meat Research Workers in Madrid, I was invited in 1983 by the Food and Agriculture Organization of the United Nations (FAO), for the first time, to serve as a consultant on slaughter house operations and slaughter house personnel training in Malawi, Tanzania and Zambia. This consultancy established a relationship with the FAO which is still flourishing today.

My preparation in Meat Science was also very beneficial to me in the introduction and development of the course contents of the final year undergraduate course, ANS 511 - Animal Products, and the postgraduate course, ANS 619 - Animal Growth and Development. In all, I have taught 13 courses to about 12500 undergraduates in the last 18 years. In the department, I have been teaching 9 undergraduate and 3 postgraduate courses. At the Faculty level, I served as the first coordinator (1987 - 1989) of the two special elective courses (SEG 001, 002) and helped shape the content and teaching of the courses to 500 - 700 non-Agriculture undergraduate students from 7 faculties and 30 departments. I have been giving the lectures on Energy Cycles (SEG 001) and Animal as Food in Modern Society (SEG 002) from 1987 to date.

Even without the application of external electrical energy, it appears that some edible animal products contain more energy (e.g. chicken egg, 6.82 KJ/g) than the body of the animals (chicken, 4.89 KJ/g). But how do we know this? In the Scientific Era, pioneer work on the determination of the chemical composition of the live body and carcass of domesticated species was done by Lawes and Gilbert in the mid 19th century in England. To date, the methods used in this area of study are grouped into three, namely:

a) Methods that are useable on carcasses alone i.e., anatomical dissection involving physical separation of bone, muscle, fat and skin. This is the "classical" approach.

b) Methods that are useable on both live animals and carcasses i.e., ultrasounds, X-ray, specific gravity, body length, circumference, fat depth; and

c) Methods that are useable on live animals alone, such as the

available to us at the *Bundesanstalt für Fleischforschung* (Federal Meat Research Centre), Kulmbach, the *Bayerische Landesversuchstation* (Bavaria State Research Station), Kitzingen and the *Technische Universität Berlin* (Technical University Berlin now Humboldt University of Berlin), all in Germany, through the imcomparable *Förderung* of the *Alexander von Humboldt-Stiftung* (Alexander von Humboldt Foundation), Bonn, Germany.

In a series of experiments using these excellent facilities (Sonaiya, 1988a, 1989a,b; Sonaiya, Ristic and Kline, 1989), we demostrated that at high diurnal temperatures (30°C - 21°C), energy intake and deposition is better regulated in the male than in the female broilers. Physiological studies based on blood parameters indicated that male broilers fed higher energy diets at these high temperatures were protected from alkalosis while females were not so protected. Careful retention studies we carried out revealed that energy retention was higher at lower temperatures (21°C) and on higher energy diets. This is because at high temperatures, energy requirement for growth was much higher although maintenance requirements were lower. In simple terms, these results indicate that young animals, and children too, raised at high diurnal ambient temperatures would have grown faster had they been raised at lower temperatures. This indicates that the slow growth and smaller body sizes of tropical livestock have physiological and biochemical bases rather than a more ominous genetic basis. I have seen the famous West African Dwarf goats that are born in the experimental station of the Wageningen Agricultural University in the Netherlands grow much taller than the WAD goats born and raised here on our University Teaching and Research farm.

We also observed a significant interaction effect of dietary energy, ambient temperature, sex and age on the fatty acids composition of broiler abdominal fat. The polyunsaturated/saturated fatty acids (P/S) ratio was increased by low ambient temperature, high dietary energy, early slaughter age and in males. Taken along with the results of carcass portioning and palatability studies that we conducted, we are able to conclude that early slaughter point for female broilers significantly improves energy efficiency of production and hence, profit. The use of abdominal fat thickness as an indicator of total body fat in broilers as well as the use of liquid nitrogen in quantitative grinding of frozen meat samples to prevent fat smearing and loss during chemical analysis for retention studies are significant contributions we made to the methodology for research into energetics of growth and development in poultry.

ANIMAL PRODUCTION SYSTEMS AND ENERGY USE

The methods of livestock production have been distinguished into three: Pastoral or Nomadic, Transhumant or Agropastoral, and Mixed farming or Settled. In terms of energy input into the production system, the direct classification into extensive, semi-intensive and intensive systems is preferred. Let me illustrate with the production of beef, the meat from cattle and the most popular edible animal product among Nigerians (Sonaiya, 1984b). The beef we eat is invariably from grass-fed, extensively-produced cattle. Conversely, in Europe and the USA, the norm is beef from intensively-produced cattle. Pastoral herds and intensive beef lots are the two extremes of a very long chain of varying levels of association between plant cropping and cattle production. In areas where domesticated animals have to move in response to the seasonal fluctuations of feed resources, livestock rearing is not only extensive, it is non-sedentary at different levels. Where movement of animals is over very wide areas, pastoralism or transhumance is practised. When the animals roam over a smaller area such as the village and farmstead, it is called scavenging. At the other end of sedentary livestock rearing is the intensive beef lots found in areas close to centres of consumption and close to access roads and means of communication. For this industrial method of fattening, cattle are completely confined to their stalls and are fed high quality grain and silage in order to provide their energy requirement.

With such a plethora of animal production systems to choose from, the factors determining that choice are myriad. Until the Oil Crisis of 1974, these factors had never included energy source. This is surprising when one notes the prodigious amount of energy (mostly from non-renewable sources) expended in animal production systems. When crude oil was $2 a barrel, this nonchalance was understandable. Now when a $12 barrel is considered unusually cheap, the cost of fossil fuel and its proportion in the animal production system has become a considerable factor.

dilution techniques for tritiated water (^3H_2O), ^{40}K and ^{51}Cr as well as the estimation of antipyrine content of body fluids.

In our study of the chemical composition of the bodies of domesticated animals, we have had the opportunity, in collaboration with senior and junior colleagues, to use each of these three methods. As an M. Phil. student under the supervision of Professor Wale Omole, I employed body length and fat depth measurements to estimate the energetic efficiency of cassava meal and cassava peel meal diets in local and exotic pigs (Sonaiya and Omole, 1977; 1983; Sonaiya, Omole and Adegbola, 1982). Fifteen years later, I directed Ayodeji Komolafe in the use of the classical anatomical dissection method of Lawes and Gilbert for the study of dietary energy partition into body tissues by Nigerian indigenous pigs. As a Research Associate of Professor Jim Stouffer of Cornell University (the father of Animal Ultrasonics) during the summers of 1984 - 1986, we developed ultrasonic procedures for instrument grading of beef. In this study, funded by the American Meat Institute, National Cattlemen Foundation, Inc., National Livestock and Meat Board and the New York State Department of Agriculture and Markets, we used the attenuation of the ultrasonic signal to estimate the amount of discontinuities in the *M. Longissimus dorsi*, which are attributable to fat globules and hence to marbling (Sonaiya, Stouffer and Cross, 1992a,b).

Regardless of the method used, the energy value of the fat free body weight is remarkably similar, indicating that fat energy is the main source of variation (from 4% to 43%) in body energy content among the various species. The animal body at chemical maturity consists almost entirely of water, protein, ash and fat. The last three chemical fraction correspond to the primary tissues of muscle, bone and fat. The efficiency of deposition of these chemical fractions varies so widely between these primary tissues. It is, in young sheep for example, 80g/d for fat, 56g/d for water, 17g/d for protein and 5g/d for ash. As the growth curve of these tissues indicate, fat deposition ensues latest and, as soon as it starts, the efficiency of conversion of feed energy to body (fat) energy drops sharply. Because muscle consists of 70 to 75 per cent water, the feed energy cost for muscle is little more than one-fourth that of fat, even though the energy costs for tissue protein and fat are both about 54 KJ/g. Therefore a reduction in fat improves feed efficiency greatly while an increase in fat deposition reduces feed conversion efficiency. With increasing age and physiological maturity, the efficiency reaches a nadir beyond which it is not economic to continue to even feed the animal. The slaughter point indicated by the energetic efficiency is usually well beyond the point of diminishing economic returns (Sonaiya, 1981, 1982).

There is no such a thing as a fat-free animal. Even newborn animals contain fat because it is essential for life. It serves as the support for membrane structures. It serves as emergency storage for energy. It protects vital organs and provides cushioning for joints during movement. Fat is a biological reality that animals are made to live with - not without! Fat is distributed throughout the body. It is under the skin, between and among the muscles, in the marrow of bones, around organs and in the visceral linings. The rate at which feed energy is channelled into fat tissue and the pattern of its deposition in the body often dictate the difference between profit and economic ruin for the animal producer.

For about 10 years, we examined the role of internal and external energy fluxes on broiler chicken production and the quality of the final product. Our first series of investigation was centred on the energy (fat) content of broiler carcasses. Our results (Sonaiya and Benyi, 1983; Sonaiya and Okeowo, 1983; Sonaiya, Williams and Oni, 1986) showed that below 1 kg body weight, fat deposition is minimal and economic but beyond 2 kg body weight, the rate of fat deposition is uncontrollable. Our attempt to control fat deposition by Manganese supplementation was unsuccessful (Sonaiya and Kabaija, 1987).

From the hundreds of body fat analyses we carried out, it was apparent that body energy metabolism was affected by environmental or ambient temperature as well as by the density and type of energy source in the feed. This, of course, is true for all classes of animals - both the simple-stomached (monogastric) animals and the ruminants with complex gastro-intestinal tracts. For poultry, we wanted to know what was the effect of constant high temperatures as compared with cycling (alternating high and low or diurnal) temperatures on energy metabolism within the body as a whole and on fat energy deposition in particular. To answer these questions, we needed environmentally controlled chambers in which temperatures and relative humidity could be artificially and automatically controlled. Such facilities were made

Agriculture, whether manual or mechanised, is an energy intensive enterprise. For mechanised agriculture in Nigeria, Adegbulugbe, Ibitoye and Akinbami (1996),estimated that irrigation pumps and tractors consumed 2,479 petajoules in 1995. Slash and burn crop technology requires few tools (cutlass and hoe) but lots of manual energy. For example, to raise one hectare of corn by slash and burn cultivation requires a total of 1,144 hours of labour equivalent to 2,699 megajoules (out of a total energy requirement of 2,828 megajoules) for a yield of 2,000 kg. In mechanised agriculture, the yield of corn per hectare is greatly increased to 5,000 kg. However, this two and a half fold increase in yield is accompanied by almost a twelve fold increase in energy consumption to 39,727 megajoules. To produce 1 kilojoule of beef, a total of 123 kilojoules of feed is consumed by the beef cattle. Milk protein is much more efficiently produced, requiring only 22 kilojoule of feed for each kilojoule of milk. Under good production conditions, a kilogram of chicken is regarded as 2.5 kg of maize and 1kg of groundnut. Now we know it to be equivalent ultimately to about 30 litres of petrol. Hence, the annual world chicken meat consumption, estimated at 37 million tons, is equivalent to 13.2 billion barrels of crude petroleum.

That there is a linear relationship between energy use and productivity is beyond dispute. Man has utilized fossil energy resources to increase food production for an increasing population. Industrial agriculture is based on the use of cheap sources of energy for power on the fields and processing units, and for the production of abundant supplies of nitrogen, other fertilizers, agricultural chemicals and other supplies. Indeed, fuel and electrical energy are essential inputs to industrial agriculture. Hence, the recent appearance of perennial scarcity and irregularities of energy supply should be of concern in relation to agricultural production in general and to the choice of production systems in particular.

Energy, whether its price or supply, brings many problems of agricultural production into a more unified perspective. The disadvantage of this new perspective is that agricultural experts do not know for certain how to evaluate the energy factor because the paradigms of industrial agricultural production were developed when neither price nor supply of energy was of any great significance. On the other hand, the advantages of the unified perspective are that the energy problem makes the search for 'low energy, intensive and sustainable agriculture' (LEISA) imperative. High energy costs and high food prices have joined forces with the environmental concerns to push us toward effective low energy, intensive and environmentally intelligent sustainable agriculture (L[EI]$_2$SA).

An important characteristic of LEISA is a greater number of jobs and an economic base to provide adequate income for those jobs. American agricultural efficiency was, until very recently, measured in terms of how few farm workers are needed to supply food, fibre and other farm products. Consistent with the development of a highly energy-intensive agricultural system has been the exodus of rural populations to urban centres. As America is also demonstrating, far more jobs are created by service industries and small scale businesses, a category into which the production, processing, distribution and consumption of animal products neatly fall. As a young researcher in Animal Products, I asked anyone who would listen to explain who I was working for; who my clients were. The large-scale intensive animal products farms did not show much interest in what seemed to me perfectly useful results on broiler growth and development and its effect on slaughter point determination. I started to look for a way to remove the asynchrony between research, extension and commercial operations in animal products supply.

The need to evaluate animal products supply systems was more forcefully brought home to me in 1987 during a poultry symposium organised by the *Deutsche Landwirtschafts Gessellschaft* (German Agricultural Society) in the folkloric city of Hameln (home to the Pied Piper). When, as the only African delegate, I was invited to inform others about the extensive rural poultry production system, I was completely at a loss for words, data or insight. I had lived with this system all my life but knew almost nothing about it even after more than a decade of poultry research experience. I thank God that the downfall of a man is not the end of his life. In response to this humiliation, I dedicated myself to learn all I could on this topic and to share such information with anyone interested. By the grace of God, within a few years I was able to so reduce my ignorance that I was invited back to Hameln in 1989 to share my thoughts about how to do research and development work in rural poultry (Sonaiya, 1989d). In 1996, in recognition of my vastly reduced ignorance of (or expertise in) poultry production systems, I was invited , in April, as a plenary speaker to the All Africa Conference on Animal Agriculture in Pretoria, South Africa (Sonaiya, 1996a); in June as an FAO consultant to the Gambia; and in September as both a plenary and symposium speaker to the XX World Poultry Congress in New Delhi, India (Sonaiya, 1996b,c).

The approach, procedure and methodologies for the study of extensive smallholder rural poultry production systems differ greatly from those of our earlier interest. To make up for lack of a significant body of literature on the topic, social science methods for acquiring information directly from people had to be used. Participatory methods i.e. questionnaire surveys and rapid rural appraisal, as well as methods for agroecological evaluation were needed to establish the structure and significance of poultry production in the rural economy. In 1989, the FAO asked me to organise an international workshop on rural poultry development research in Africa. This workshop, and its proceedings - "Rural Poultry in Africa" - which I edited, made available a mine of unpublished data about breeds, housing, health, feeding, management and marketing of rural poultry in Africa.

From a detailed review of this emergent literature, I (Sonaiya, 1990e,f) surmised that Newcastle disease was the first priority problem, that night shelter was absolutely necessary, that interventions in brooding up to 4 weeks, and in energy feed supplementation were required in order to improve productivity of rural poultry. Using equipment grants from the Alexander von Humboldt-Stiftung (Germany) and research grants from the International Foundation for Science (Sweden) and the International Development Research Centre (Canada), we set out to study in as much detail as we could, every facet of the rural poultry production system.

RURAL POULTRY RESEARCH AND DEVELOPMENT

Rural poultry development is not a new thing. Development efforts in Nigeria date as far back as 1919 (Sonaiya, 1989d). Various schemes have been executed but the approach in most of these schemes had been toward genetic improvement and/or vaccination. The most widespread strategy was the cockerel exchange programme or *Opération Coq* as it is called in Francophone countries. Wherever genetic improvement strategies have been combined with either vaccination, feeding and housing improvement or farmers training, better success had been achieved.

Development of rural poultry production can contribute significantly to rural development by improving family nutrition and incomes, employment opportunities and promoting equity for women. Rural poultry development has been found to be ideal for rehabilitation of refugees and victims of disasters and wars. Somali nomads who lost most of their cattle to droughts accepted poultry and its products as substitutes for cattle and beef, respectively. Widows of the Ugandan civil war were rehabilitated by the Catholic Church of Uganda through a rural poultry programme initiated in 1987.

Before our efforts, research into village poultry production in Nigeria was negligible; far less than the importance of the sector. The 1992 livestock population census showed that of the 114 million poultry, 104 million were held in the rural areas. All classes of poultry are raised in the villages: chickens, ducks, geese, guinea fowls, pigeons and turkeys. In the forest zones, flock composition is heavily skewed towards chickens while guinea fowls are more important in the savanna and sahel zones. About 72% and 70% of rural poultry producers in the north-west keep turkeys and ducks, respectively (Sonaiya, 1990a). These rural poultry make the greatest contribution to the supply of meat and eggs for the average Nigerian. For example, annually, about 89% of total poultry meat consumed and over 25% of total poultry eggs consumed come from rural flocks. Research and development work that will increase productivity of rural poultry by 10% will contribute far more poultry products than huge investments in industrial poultry that will lead to a 10% increase in poultry-housed production. In order to solve the problems of rural poultry such as high mortality, low productivity and seasonal supply of products, it is necessary to develop cost-effective improvements for application at the village level. This was the guiding principle for our rural poultry work.

A Rural Poultry Research Project (RPRP) was conceived in 1987. The objective was to study the whole system of traditional poultry production and to develop practical interventions for enhancing the productivity, efficiency and profitability of the village flocks. The initial

phase was a series of field surveys of traditional poultry management in villages located in 10 states of the Federation - Delta, Edo, Ekiti, Kano, Kwara, Lagos, Ogun, Ondo, Osun and Oyo - at different times. The survey teams for most states were multidisciplinary in nature and comprised at different times, Prof. Oluyemi, Department of Animal Science, University of Ibadan; Dr. Mrs Matanmi, Dr. Mrs Daniyan, Dr. Odubote, Mr. Olori, Mr. Akinlade and Mr. Omoseibi of our department; Dr. Laogun and Dr. Miss Akande of the Department of Agricultural Extension; Dr. Oguntade and Dr. Idowu of the Department of Agricultural Economics of our Faculty.

These surveys revealed that the average flock size was about 20 birds with a male to female ratio ranging from 1:1 to 2:3 and the larger the flock size, the more males there were. The classes of poultry kept by villagers were chickens, ducks and pigeons in the south; chickens, ducks, guinea fowls, turkeys and pigeons in the north. Exotic and native chickens were kept including a strain obtained only from the migratory Fulani pastoralists which is bigger and grows faster than the non-Fulani chickens. The common 'duck' in Nigeria is the black and white Muscovy (*Cairina moschata*) which is not a duck at all as it belongs to the family of geese. The common guinea fowl (the only poultry species indigenous to Africa) is the grey helmeted *Numida meleagris*. Chicken mature weight, achieved at about 56 weeks, ranged from 1.0 to 2.5 kg. Each year, hens laid eggs in 3-4 clutches with 5-15 eggs per clutch. Hatchability is very high but never 100% especially during the rainy season. Chick mortality is very high due mostly to predators, disease, car accidents and floods. The birds scavenge for insects, earthworms, maggots, green leaves and stone grits, and are supplemented with grains (maize and sorghum) 3 times daily. Major outbreaks of Newcastle disease regularly occur at the peak of the rains (June/July) and the dry season (January/February) during which mortality reaches 70-100%. Farmers reported that prevention of Newcastle disease was possible when birds drink a water extract of a local pumpkin ('Tagiiri' - *Lagenaria breviflora*) mixed with pepper ('Ata wewe' - *Capsicum frutescens*).

All rural poultry depend on human habitation for their feed and the ratio of poultry to the farming population is usually about 1:1.3. Free range birds do not receive regular feeding but survive through scavenging around the village. Energy is the first limiting nutrient as the food available on the range contains a lot of crude fibre. One way to increase energy supply for egg production is to provide grain supplements in the morning and evening as most eggs are laid in the evening and morning. Obi and Sonaiya (1995) reported that their village respondents gave to each bird daily, an average of 19g of maize and 11g of sorghum supplements. A very important factor in relation to feed consumption and efficiency is water consumption. In subhumid and humid zones, 25-40% of smallholders do not specifically offer water to free range birds.

We have been able to follow up virtually every facet of this fascinating system - genetics and breeding, health care, feeds and feeding, housing and management, marketing, production economics and extension methods. To support this project, a brand new Poultry Meat Research Laboratory was developed with funds from the International Foundation for Science, the Alexander von Humboldt Foundation and the European Commission and equipped to study poultry from the egg to the table. Twenty-two papers, four MSc theses and a PhD thesis plus countless final year BAgric project reports have come from this aspect of our work.

The varieties of chicken reared in the villages are usually differentiated by feather colour and other external characteristics. Some, however, are reported (Sonaiya, 1990e) to possess genes which affect adaptability and productivity in hot climates. Examples are the genes for featherless neck (*Abolorun* in Yoruba or *Pingi* in Hausa), dwarf body type (*Arupe* or *Durugu*) and frizzled feather (*Asa* or *Shazumama*). Victor Olori (1992) evaluated the chickens owned by the cattle Fulani and compared them with the chickens of Non-Fulani people and showed that there was a genetic basis for the superiority of the Fulani birds which we later found are supplied to other Fulani groups by the Bororo from inbred closed nucleus flocks that have been selected for meat production and hardiness. From on-farm and on-station research, Olubunmi Idowu (1992) showed that unconventional feedstuffs such as fermented maize residue (*eeri* from making *ogi*), cowpea testa (discarded during making *akara* and *moin-moin*) and palm oil sludge (obtained from the *eku* where palm oil is traditionally extracted) can form the basis of a supplemenatary ration for scavenging chickens. Sonaiya (1993b) reported the use of these unconventional feedstuffs as a supplement for scavenging chicken in an unbalanced ration containing 110g protein and 15MJ metabolizable energy per kg feed.

Supplementation intake as low as 8g/day increased the body weight gain of scavenging grower chickens.

Generally, productivity of birds increases directly with the level of management. Under the free range and backyard systems, egg production per hen per year is 30-40 for ducks, 60-80 for turkeys, 30-100 for chickens and 100-120 for guinea fowl. The guinea fowl is an exception for while it supplies 53% of total poultry eggs traded and consumed in rural areas, its eggs are merely gathered from the free range. Hatchability of poultry eggs is consistently about 80% in all regions of Nigeria but mortality is at least 50% and average daily gain is about 6g for grower chicks and keets.

Many diseases plague rural poultry including Gumboro, coccidiosis, fowl pox, fowl typhoid, fowl cholera and external parasites like lice and mites. Newcastle disease is the most important disease causing very high mortality. Vaccination of rural birds against Newcastle disease is an obvious priority. With Olutayo Obi (1995), we conducted on-farm studies on the effect of vaccination agaisnt Newcastle disease and of feed supplementation on the productivity of scavenging village chickens. The results indicated a significant increase in growth rate, egg production and chick survival.

In order to disseminate this new knowledge coming from us and from all over Africa, we initiated in 1989, at the workshop held here at Ile-Ife, the African Network for Rural Poultry Development (ANRPD). This is an independent voluntary association targeted at researchers, policy makers, educationists, development agencies (including NGOs) and smallholder farmers operating in or interested in Africa. By 1995, there were 306 members from 34 African, 9 European, 3 Asian, 2 South Pacific, 2 South American and 2 North American countries. Two international organisations - the Food and Agriculture Organization of the United Nations (FAO) and the European Community's African, Caribbean and Pacific's Technical Centre for Agricultural and Rural Cooperation (CTA) - have shown particular interest in the Network since its formation. The Network publishes a Newsletter in English and French two times a year and a Directory of Rural Poultry in Africa once a year. Every two years, there is a meeting and general assembly of the Network members. At the last such meeting in December 1997 at M'Bour via Dakar, Senegal, it was decided to widen the scope and coverage of the Network which was renamed the International Network for Family Poultry Development (INFPD) and its Newsletter is now published on the Internet. I have had the privilege to serve as the Coordinator of the ANRPD and now INFPD for the last ten years and as editor of its newsletter and the published proceedings of its international conferences.

Between 1992 and 1997, we participated in a cooperative research project funded by the European Commission's Science and Technology Development Programme. The cooperating institutions and scientists were: Prince Leopold Institute of Tropical Medicine, Belgium - Dr. Ir. F. Demey and Ing. R. Baelmans; Universidad Tecnica de Oruro, Bolivia - Ing. O. Iñiguez; Humboldt University of Berlin, Germany - Prof. Dr. P. Horst, Prof. Dr. Anne Valle Zarate, Dr. P.K. Mathur and Dr. K. Wimmers; Central Avian Research Institute, India - Dr. D.P. Singh; and Obafemi Awolowo University, Nigeria - Prof. E.B. Sonaiya and Dr. I.K. Odubote. Overall coordination and leadership was provided by the most distinguished and most experienced Prof. Peter Horst of Germany. Our particular objective in Nigeria, within the larger project objective, was to evaluate how local poultry populations vary in their ability to produce and to resist diseases. A total of 28 populations (1,570 locals and 1,192 exotics) were evaluated, on the University Teaching and Research Farm, for physical appearance and production performance. We also searched for genetic differences between collections from ecological zones in Nigeria - Kaduna and Jos from the Guinea savanna; Makurdi and Ilorin from the Derived savanna; and Nsukka and Sagamu from the Rain forest zones.

Our results (Sonaiya *et al*, 1995, 1998) showed that our local chickens are superior in disease resistance to the exotic Rhode Island Red chickens. Disease resistance or immune competence was determined by our Belgian partners using sheep red blood cell and phytohemagglutinin to examine the humoral and cellular immunity and complement activity. Our German partners carried out polymerase chain reaction (PCR) genotyping using 22 polymorphic microsatellite loci from the samples we took and prepared for DNA analysis. Heterozygosity, Nei's distance and allele sharing were used to measure genetic variation and similarity, respectively. These methods grouped the Nigerian local chicken ecotypes together with the Rhode Island Red while the local chickens from Bolivia, India and Tanzania were distinct

from the Rhode Island Red. This is an indication that there has been a great deal of gene mixing between the Nigerian local and the Euro-American commercial lines as we previously suggested (Sonaiya, 1989d; 1996b). Nonetheless, the Nigerian collections showed a higher mean heterozygosity than the Rhode Island Red. Although the collections from the different ecozones did not differ sufficiently from each other to qualify as separate strains, there are indications of adaptations to the ecoregions which may be explored by inbreeding and selection in order to develop Nigerian poultry breeds for different purposes.

In order to apply the results of this research, we are continuing to further evaluate the hens of the Nigerian chickens and their crosses with Rhode Island Red for egg laying performance and persistency and feed efficiency. The egg production, egg weight and feed efficiency will be related to income from a layer enterprise. The cocks will be distributed to smallholder poultry producers and the survival and breeding performance of these cocks will be monitored. In a pilot study we conducted with smallholders here on campus, we found indications that the size of the cock determined its opportunity to mate with the local hens on the free range. In cooperation with the Songhai Centre in Porto Novo, Benin Republic, (a non-governmental organization for training, research and development in L[EI]$_2$SA, rural empowerment and philosophy of development whose Director, Father Geoffrey Nzamujo, O.P., shared with President Jerry Rawlings of Ghana the 1993 Africa Prize for the fight against World Hunger) we have been studying the performance of the first and second generations of Rhode Island Red birds. The results so far indicate very good hatchability of the eggs and impressive growth performance of the chickens.

The crosses between Nigerian locals and Rhode Island Red are currently being backcrossed to their parents. This is part of Adetayo Adedokun's M. Phil thesis research. All chicks hatched will be tested on-station and the pullets and cockerels distributed for on-farm testing. The line with the best adaptation to the smallholder poultry situation will be multiplied and distributed to research stations and farmers throughout the country. It is hoped that the improvement in performance will result in increased incomes from extensive poultry production. This phase of applied research will continue to involve our students (undergraduate and graduate) as well as research and extension personnel from other institutions as well as farmers.

ENERGY CONSERVATION AND ENVIRONMENTAL SUSTAINABILITY

The Agricultural Policy for Nigeria (1987) has the following objectives for livestock production:

1. Make Nigeria self-sufficient in livestock products;
2. Improve the nutritional status of Nigerians by provision of livestock products;
3. Provide locally all necessary raw material inputs for the livestock industry;
4. Allow for a meaningful and efficient use of livestock by-products;
5. Improve and stabilise rural incomes from livestock production and processing;
6. Insure the rural livestock farmer against the risks to livestock production;
7. Provide more rural employment through livestock production and processing;
8. Maintain the ecosystem for expanded livestock production.

Modest contributions have been made towards, the achievement of these objectives through our research efforts and services rendered to various public institutions. I served: on the expert committee that prepared the livestock information packages for the Federal Directorate of Food, Roads and Rural Infrastructures (DFRRI) in 1989; as expert consultant to the Committee on Vaccination of Local chickens of the Federal Department of Livestock and Pest Control Services in 1990; on the Second Livestock Development Project's National Animal Research Advisory Committee's Sub-Committee on the Improvement of Local Poultry in Nigeria in 1991; as a member of the Poultry Industry Sub-Committee of the National Livestock Development Committee in 1991-1992.

Perhaps the most consistent avenue towards the achievement of these livestock objectives that I found was my service in the Presidential Task Force for the Formulation of Alternative Feedstuffs for Livestock. This Task Force directly contributed to the achievement of objectives 3 and 4 and indirectly to objectives 1 to 7. The Task Force worked between 1989 and 1992 and produced alternative diets which did not contain any grains or incorporated such a high level of crop and animal

by-products that made them far cheaper than conventional feeds. But what about the last livestock objective concerning ecological maintenance?

Within the last 10 years, there have been increasing pointers to the unsustainability of animal production in most farming systems. The primary concern is with resource depletion and degradation - grassland degradation, loss of soil-conserving vegetation, loss of nutrients and organic matter from soils, methane emission by ruminants that contribute to global warming, ammonia emissions from intensive pig and poultry farms or cattle feedlots that result in acid rains, nitrates in water from animal wastes and rapid loss of animal genetic diversity. In addition, questions have been raised about health hazards from meat and egg consumption and about the propriety of feeding grains to livestock. The challenge now facing animal scientists is not only to contribute towards increasing the quantity and quality of animal products and the income of livestock farmers but also to work towards enhancing the role of livestock in conserving natural resources - land, water and biota - and minimizing environmental damage.

Animal genotypes and production systems must match both production resources and the environment. From a practical viewpoint, the locally available livestock breeds and feed resources, including the grasslands, are the natural resouce base for animal production. Without long-term conservation and improvement of the other natural resources, animal production itself is endangered. Production resources, economics and consumer demands all change with time and animal production systems must change accordingly.

It should be noted that livestock is beneficial to the environment by returning nutrients and organic matter to the soil and by utilising range, marginal lands and fallow fields in a productive way. Livestock contribute to rural energy in the form of draught animal power (DAP) and fuel. These constitute a major renewable source of rural energy. DAP is still a dominant source of farm power in Asia, as it is in northern Nigeria. In the Philippines and Thailand, FAO, in 1989, estimated that 72% of all farmers used animal power, 18% used manual power, 8% used animal and mechanical power and only 2% used mechanical power (i.e. tractors) alone. There is a greater awareness of DAP as an economic and efficient option for smallholder farmers particularly now that subsidies for tractors are fast disappearing. In Morocco, for example, the cost of using a mule is half the cost of using a tractor. Here in Nigeria, the increasing establishment of permanent herds of cattle in the derived savanna areas of the south point to the potential of using cattle for draught power in addition to their use for milk and meat.

Fuel from livestock production is generated in the form of dung cakes or the leftover ligneous matter of tree fodders and sugar cane and such feedstuffs. These materials can be burnt directly or used for biogas production. The biomass producing capacity of perennial crops in the tropics is twice as much as of those in the temperate zones. The energy producing capacity of this biomass exceeds the current energy consumption as fossil fuel. Indeed, sugar cane, for example, can be used as a source of feed, energy and chemicals as its fibrous residues can be converted into chemical feedstock by gasification.

Environmental pollution from animal production may arise in the form of:
i) ammonia and nitrous oxide emissions from intensive production units;
ii) methane produced during digestion by herbivores and manure fermentation; and
iii) nitrates in water emanating from animal manure.

In Nigeria at present, only methane emission from ruminants is of significance as intensive poultry and pig production is still very low. It has been estimated that methane accounts for about 20% of green house gases in terms of CO_2-equivalent while CO_2 itself accounts for some two-thirds of the green house gases. Of the total methane production, some 20% is associated with livestock; three-fourths of which is produced by ruminants. Methane production is however, influenced by animal characteristics as well as feeding and management practices. Improved feed utilization efficiency usually reduces production of methane in the rumen. With adequate supplementation of rumen nitrogen and the supply of by-pass carbohydrates and proteins which will supply sugars and amino acids to the abomasum, local energy and protein resources including low quality roughages can be used. Many innovative feeding programmes have been developed: sugar cane based systems of livestock

production; the use of bananas, plantains, roots and tubers as energy sources; the urea treatment of straw (of rice and other cereals) to improve digestibility and feeding value; the use of molasses-urea blocks for supplementing low quality roughage; and the use of legume trees and other fodder trees as protein sources for livestock.

The intensified use of resources through nutrient recycling in mixed farming systems is a major strategic option for sustainable agriculture. Integration of livestock with annual crops, tree crops and fish ponds greatly increase total food production from available resources and minimizes environmental and economic risks. For example, grazing under tree crops expands the scope for ruminant production, particularly sheep and goats. Grazing under palm trees increases palm yields. Integrating pastures, fodder shrubs and trees doubles cattle carrying capacity, increases liveweight one and half times and firewood two and half times. In Asian countries, integrated livestock-fish systems indicate that in a polyculture of fish covering different strata of a pond consuming pig and duck manure, 5-7 tons of fish per hectare per year can be harvested without a feed supplement for the fish.

Sustainable development is the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable (FAO, 1989). Livestock strategies must be judged according to their likely impact on economic, ecological, ethological and sociological issues (Preston and Murgueitio, 1992). Economic sustainability requires optimising the use of available natural resources. Ecological sustainability requires that the production system will result in:

i) the reduction of the principal greenhouse gases - CO_2, CH_4
ii) reduced contamination of soil and water resources;
iii) an effective control of soil erosion; and
iv) on-farm production of energy from renewable resources.

Ethological concerns relate to potential effects of production systems on animal welfare and the safety and consumer acceptability (wholesomeness) of the foods produced in such systems. Sociological issues require that employment opportunities are increased.

Strategies for sustainable livestock production must aim at an increased integration between crops and livestock production. The strategies will also involve a change in cropping pattern through the selection of crops which will maximise biomass production and nitrogen fixation with minimum imported inputs. They must match the competition for labour for livestock and crop production by the introduction or intensification of draught animal power. Another part of the strategies should be the use of multipurpose animals that provide DAP, milk and meat, and the introduction into the production systems of small and non-ruminant species that are well adapted to the forage resources, by-produts and wastes produced by the farms.

This question of sustainability is likely to engage my research and teaching efforts for the coming years by the grace of God. How can animal products be obtained in a sustainable way, in a way that benefits more directly other agricultural enterprises such as crops (annual and permanent), fish and forestry?

Consider the debate between those that pin their hopes for livestock development on the transfer of the most advanced technology and those that rely on modification of traditional technology to make them more appropriate and more likely to create employment rather than capital. The technology transfer group says that what adds to social well-being is the volume of goods produced, not the number of jobs created, i.e., what is important is to produce more food, not how it is produced or who produces it. This position, which has enjoyed the pride of place up to date, seeks to replace traditional livestock systems with "modern" ones. The failure of our "modern" poultry industry indicates the inadequacy of this option.

The better option is that of technological blending, defined as the integration of newly emerging technologies with traditional modes of production to ensure higher productivity. This is exemplified in the United States and Europe by "precision agriculture," the use of advanced technology to increase yields and reduce environmental impact. In industrial farming, a cultivated field is regarded as a single tract of land, and pesticides, herbicides and fertilizers are uniformly

dispersed across the entire area. But each field can vary widely in terms of soil chemsitry and weed concentration. One section might be infested with weeds, for example, and need heavy doses of herbicides, while another might be naturally weed-free. Precision agriculture enables farmers to tailor their use of chemicals to the requirements of small patches of soil, sometimes even on the scale of individual plants. As a result, the use of agrochemicals - and the ecological damage they cause - can be reduced. In animal production, such an approach can include, for example, computer control of biogas production from manure; computer control of grazing or scavenging by animals on the range; and development of transgenic poultry that can digest high fibre diets. In any case there is no alternative to a thorough understanding of traditional peoples and their indigenous technology. The spread of scientific practices and methods starts first with the spread of a technical culture. This means that scientists and technologists must go to the villages to measure, weigh and observe along with the farmers.

In order to initiate this technological blending, we must pay attention to our institutions and procedures for training, research and extension. The training of manpower for agricultural development must not only be multidisciplinary (which it is) but must emphasise the blending of disciplines, of science and tradition, of old and emerging technologies. Such a training must be led by relevant and appropriate research. The 16 Faculties of Agriculture and 3 Universities of Agriculture must continue to engage in relevant teaching, research and extension by reappraising their programmes in relation to sustainability, energetic efficiency and environmental awareness.

CONCLUSION AND RECOMMENDATIONS

Most of our livestock are held in small rural farms. Their development by blending new technology with traditional methods can contribute significantly to the generation of rural employment and expansion of food production. Such a development requires skills, perspectives and orientation often not included in the academic training of agricultural research scientists, including communication, community development, qualitative research, farming system analysis, gender analysis, design and management of on-farm trials, and participatory monitoring and evaluation. How can we equip mature research scientists with these skills so that they can have enough confidence to apply them? I recommend the initiation of a faculty-wide 'Agricultural Development Forum' to serve as a vehicle for achieving this objective.

Agricultural research serves a wide range of clients, not only low-income farmers, or farmers in general, but also processing industries, other scientists, and government ministries and parastatals. With all types of clients, the key dialogue is between what 'science' has to offer and what clients require. How can we get the farmers to participate in setting research agenda and goals? Farmers in the middle and higher income ranges participate through the market by hiring consultants or by exerting pressure through lobby groups or by vocal response to the technologies on display during visits to research stations. Low-income farmers are less likely to participate either via market or by making vocal demands; their farming systems are difficult to replicate on research stations. Effort is required by researchers to understand these systems and to experiment on-farm with farmers. Attitudinal changes are required at the institutional level in the following areas:

A committment to producing results of use to an identified set of clients;

Performance criteria, the means of assessing work against these criteria, and the types of reward and incentives provided must all be geared to success in delivering technologies to meet clients' needs;

Scientists need specific training in the methods of participating with farmers.

In order to identify appropriate technologies that will improve the performance of locally available animal and feed resources, there is a need to coordinate, codify, amplify and broadcast across state and language barriers the individual efforts undertaken at various locations in the country. We must find, collate, share and crosscheck all procedures which "minimise risks and optimise production with low-cost inputs; conserve and improve the farming system resource base; minimize wastes and environmental degradation; and recycle wastes for animal feed or energy supply (Qureshi, 1993)." This requires further adaptive research and development effort to put in context prevalent ideas and technology. Such adaptive efforts require a multi-disciplinary collaboration as can be found in a flexible programme structure rather than rigid departmentalization. For instance, there are

My research collaborators: Professor James Stouffer of Cornell University, who supervised my PhD and remains a dear friend and advisor, Professor Peter Horst of Humboldt University of Berlin, Professor Anne Valle Zarate of Bonn University, Professor Werner Bessei formerly of FAO and now of Hohenheim University, Stuttgart and Professor Rene Branckaert of the FAO.

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many complementarities among departments dealing with soil fertility, crop production and livestock production which would bring substantial benefit to low-income farmers if more fully exploited. The Faculty and University Research Committees, in addition to multidiscplinary emphasis, must require identification of beneficiaries in all research project proposals submitted for funding.

Barely 18 months to the beginning of the 21st Century, the challenges that face and will continue to face agriculture are related to energy supply, use and efficiency, environmental consideration and their impact on economic sustainability. Our Faculty of Agriculture and indeed the whole of Obafemi Awolowo University must find and occupy a leading role in addressing these challenges to the continued supply, now and in the future, of food, fibre and fuel.

I propose the establishment of a Programme on Environment, Energy and Sustainable Agriculture Novel Technologies (PEASANT). This programme should involve the Faculties of Agriculture, Technology, Environmental Design and Management, Science, Social Sciences, Adminstration, Arts, and Law in a multidisciplinary effort to explore the ramifications of the challenges facing our food production systems. The Programme should be developed in collaboration with the Energy Commission of Nigeria, the Federal Environmental Protection Agency, both in the Presidency; the Federal Ministries of Agriculture, Mines and Power, Women and Social Development, Science and Technology, Finance and Justice; the Nigerian Academy of Science, the Nigerian Chamber of Commerce, Industry, Mines and Agriculture (NACCIMA), Farmers' organizations and non-governmental organizations in and outside Nigeria.

I have just received notification that my project proposal on the development of an environmental education curriculum for sustainable agriculture has been approved by the UNESCO general assembly for inclusion in Nigeria's national programme for 1998 and 1999. This project can serve as the seed for the mighty tree that PEASANT will become.

I propose that one of the activities of this Programme should be the organization of an Annual Obafemi Awolowo University Conference on Environment, Energy and Sustainable Agriculture. This PEASANT conference will provide a yearly forum for the examination and reevaluation of policies, strategies and technological developments in these areas which are vital to the survival and development of the Federal Republic of Nigeria in the 21st Century.

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