Official Publication of the Faculty of Basic Medical Sciences University of Ibadan, Nigeria

*Arch. Bas. App. Med. 4 (2016) 101 – 108*
*www.archivesbamui.com*

**ARCHIVES OF BASIC & APPLIED MEDICINE**

*Review Article*

# Biotechnology and the Food Security Question in Nigeria

**'Tola Badejo**
*Department of Zoology, Obafemi Awolowo University. Ile-Ife, Nigeria*

**Abstract**
In this paper, biotechnology is narrowed down to all aspects of it that can boost food production and prevent hunger. Food security in a country is defined as a situation where majority of its population have access to food of adequate quantity and quality consistent with decent existence at all times while food insecurity on the other hand is seen as lack of access to enough food which can be either chronic or temporary. The backsliding of a situation of food security in Nigeria in the pre-colonial era to the current situation of food insecurity was traced to inconsistencies in and ineffectiveness of agricultural policies of successive governments since independence. Biotechnological techniques in the agricultural sector that have the potentials to rescue the food insecurity situation is divided into three fields: crop production (microbial inoculation of plants), livestock production and food processing. The paper highlights certain unresolved problems in agricultural biotechnology techniques and stresses that research attention in Nigeria must be focused on the purification of local biotechnology processes in food processing and production of beverages. It is suggested that application of modern biotechnology in the areas of crop and livestock production should be intensified bearing in mind the limitations of modern biotechnological techniques such as: tissue culture, genetic engineering and solid state fermentation. These limitations are identified as technical problems, high cost of operation and inability to ensure sustainability. The idea that biotechnology is the magic bullet solution to all of agriculture's ills is considered untrue while empirical evidence is provided on the fact that the prevalence of hunger in a country has nothing to do with the size of the human population. Examples of sparsely populated and hungry nations are provided. It is stressed that enough food is being produced for the world's teeming population, but food insecurity exists in many countries due to poverty, inequality and lack of access to food. The paper urges Nigeria and other developing countries to, as a matter of priority and expediency, identify areas of appropriate biotechnology that could be improved upon in synergy with sustainable biotechnology so as to evolve a sustainable agricultural system which is ecologically sound, economically viable, and socially responsible.

**Keywords:** Biotechnology, food production, national development, Nigeria

## INTRODUCTION

"Biotechnology is broadly defined as "any technique that uses living organisms or substances from those organisms to make or modify a product, improve plants or animals, or develop microorganisms for specific uses" (Persley, 2000). This requires the integration of several scientific disciplines such as: biochemistry, biology, microbiology, chemical engineering, process engineering, etc. in a way that optimizes the exploitation of their potentials (Badejo and Okoh, 2001; Badejo 2011). In the strict sense, biotechnology is the application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services. When such goods and services are in the agricultural or food production sector, then biotechnology narrows down to all aspects of it that can boost food production and prevent hunger.

The focus of our discourse at this conference is Health and Sustainable Development. Food production and prevention of hunger therefore are quite relevant because they are inextricably linked with Health and Sustainable Development.

Is there Food Security in Nigeria?

Perhaps the best approach to addressing the question of food security in Nigeria is to define food security and thereafter do a comprehensive review of recent research findings on food security in the country.

According to Reutlinger (1983) and Idachaba (2004), a country is food-secure when majority of its population have access to food of adequate quantity and quality consistent with decent existence at all times. What this implies is that food security can be taken to mean access by all people at all times to sufficient food for an active and healthy life (Reutlinger, 1985).

Perhaps, a very convenient way to understand food security is to define food insecurity. Food insecurity on the other hand represents lack of access to enough food and can be either chronic or temporary. In chronic food insecurity, which arises from a lack of resources to produce or acquire food, the diet is persistently inadequate (Adeoti, 1989).

In the 20th Century, food insecurity was seen as a failure of agriculture to produce sufficient food at the national level. The 21st Century notion of food insecurity has advanced beyond this. Food insecurity is now seen as a failure of livelihoods to guarantee access to sufficient food at the household level. (Clover, 2003).

**Author for Correspondence:* +234803 8352 321
E-mail: mbadejo@yahoo.com

*Paper presented at the Fifth Unibadan Conference of Biomedical Research (UCBR-5), University of Ibadan, July 13-15, 2016*

It is quite disheartening to note that in the pre-colonial era, Nigeria did not have to contend with the problem of food insecurity. Peasant farmers were able to feed their households and the system was able to feed her citizens and at the same time export to neighbouring communities the surplus food items. Every region of the country specialized in the production of specific food or cash crops, The North produced groundnut in excess of local demands, the West produced cocoa, the east produced oil palm and kernel heaps while the Midwest was known for the rubber plantations that yielded foreign exchange. Crude oil discovery in 1956 and exportation of it in 1958 changed the whole situation. Hoes and machetes went on holiday and the door was locked to sustainable mechanized farming.

Omonona and Agoi (2007) investigated the incidence of food security in urban households in Nigeria and reported that food insecurity in Nigeria is influenced by factors such as the age, gender, profession and level of education as well as income of household heads. They concluded that Nigeria was yet to attain food security as defined by the World Bank. According to the World Bank, the main goal of food security is for individuals to be able to obtain adequate food needed at all times, and to be able to utilize the food to meet the body‘s needs thereby ensuring an active and healthy life.” (World Bank, 1986). Food security obtains when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 1996).

Akinyele (2010) took a glimpse at rural food and nutrition security in Nigeria and declared that malnutrition is widespread in Nigeria especially in rural areas. He reported further that Nigerians are vulnerable to chronic food shortages, erratic supply, poor quality food, and fluctuating food prices and concluded that the huge investment in ensuring food and nutrition security for Nigerians has recorded limited success.

In order to guarantee food security in Nigeria, Attah (2003) suggested the following strategies: Rural development; Easy access to basic farm inputs; Adequate budgetary allocations; Appropriate policies for food sub-sector; Political stability; Reduction in poverty at the rural level; Peasant Farmers’ Education. None of these measures can be faulted when considered individually. However, when viewed as a whole, Agricultural Biotechnology is conspicuously missing. This is not surprising because this concept had never featured in successive agricultural policies of the country since independence in 1960. It was only recently that there was a spirited effort by the Federal Government of Nigeria to regulate and control biotechnological research in the country. The National Biotechnological Development Agency (NABDA) was established through Federal Executive Council approval on the 23rd of April, 2001 with a mandate to coordinate, promote and regulate the development of biotechnology in the country (see Badejo, 2011).

## A review of Nigeria’s agricultural policies since 1960

The first republic witnessed uncoordinated efforts between the regions in respect of agricultural policies. The gains of cocoa production in the Western region are more visible today than the gains of the groundnut pyramids in the North and palm oil in the east. When the military truncated democracy in 1966, there was a civil war and food insecurity became aggravated. The military embarked on a massive importation of rice in the early 1970s to ensure food security but this could not tackle the problem of food security. There were suggestions that the over bloated army which became redundant after the civil war should be drafted to the farm to boost agricultural production. This policy option was discarded for security reason. In 1976, the military government under a different leadership embarked on Operation Feed the Nation, (OFN). Government advised the citizenry to plant anything, plant something, anywhere. This policy somersaulted because it lacked adequate planning and intellectual input. Unfortunately, the successive civilian government that took over in 1979 embarked on a mere change of name from OFN to Green Revolution without any significant change in conception, content or context of the policy. When this civilian government was truncated by the military in 1983, the country witnessed 14 more years of policy somersaults under the military. There was the Directorate of Food, Roads and Rural Infrastructure, DFRRI in 1985 which was supposed to be a comprehensive, integrated programme for massive food production and rural transformation. It was a colossal failure.

When democracy was restored in 1999 greater attention was given to food production. A number of food security initiatives were launched. As listed by Bello, (2004) and Ojo and Adebayo (2012), they include:

1. Special Programme for Food Security (SPFS)
2. Root and Tuber Expansion Programme
3. Fadama Development Project
4. Community-based agricultural and rural development schemes
5. Provision of infrastructures
6. Collaboration with the United States, the government commissioned the American-based International Centre for Soil Fertility and Agricultural Development (ICSFAD), to study the problems militating against increased agricultural production in the country.
7. Banning of importation of some agricultural products.
8. Selling of fertilizers to farmers at subsidized rate
9. Facilitating increased investment in agriculture by strengthening the financial capacity of state-owned agricultural banks to grant soft-loans, and pleading with the private commercial banks to extend low-interest loan facilities to large-scale and small scale farmers.

In spite of all these policies, food insecurity still stares us in the face in Nigeria.

## An overview of Biotechnological techniques

The roots of biotechnology were established around 6,000 BC when the Sumerians and Babylonians in the Near East started beer and wine production. Egyptians were baking leavened bread by 4,000 BC. During this period, characteristics of microorganisms were used without any understanding of the processes involved. It was not until the 19th century that Louis Pasteur [1857-1976] demonstrated the fermentative ability of microorganisms (Lubberding, 1990). Today, biotechnology has expanded tremendously beyond fermentation processes. Advances in molecular biology, genetic engineering and waste treatment technology have widened the scope of biotechnology. In the agricultural sector, application of biotechnology can be divided into three fields: crop production, livestock production and food processing.

**Crop production:** Various biotechnological techniques by which increased crop productions have been enhanced include tissue culture, microbial inoculation of plants, diagnostic tests, protoplast fusion and plant genetic engineering.

Tissue culture technique is very recent being less than 70 years old. The aim is to regenerate whole plants from single cells in the laboratory and later transfer the plant to the soil. This simple technique has been used to micropropagate cultivars and to cultivate virus-free plants from virus-infected plants. It has also been used to improve plants that grow slowly and it has been possible to select cells with specific characteristics from any part of the plant, manipulate the media in which they grow and as a result, produce plants with characteristics different from the parent plant. One problem that is yet to be resolved from tissue culture is the regeneration of whole plants from cells. It is only in rare cases that this has been achieved (UNDP, 1989). The application of tissue culture requires a sterile workplace. It is labour intensive, time consuming and costly. According to Broerse (1990), most plants produced by tissue culture in industrialized countries must be sold for more than $0.25 per plant. Unless there is a major breakthrough in tissue culture research that reduces the cost of production tremendously, application of tissue culture in Nigeria will bring about an increase in the cost of food.

Microbial inoculation of plants is particularly useful in the areas of improved plant nutrition and pest control. Because soils are often low in nitrogen content, good plant growth often means supplementing soil nitrogen with NPK fertilizers which are expensive to produce and therefore too costly for many small scale farmers to buy. Fortunately, some plants can form mutually beneficial relationship [symbiosis] with microorganisms which convert atmosphere nitrogen to ammonia, which is then used by the plants to make protein (Roskoski, 1992). Nitrogen fixing bacteria, mycorrhiza fungi and plant growth-promoting rhizobacteria are various biological agents whose artificial inoculation into the soil can increase the nutrient status of soils. Microorganisms that are capable of fixing atmospheric nitrogen include the blue-green algae (Cyanobacteria); soil bacteria such as Azotobacter and Rhizobium and Actinomycetes. These nitrogen fixers possess the enzyme nitrogenase, which converts atmospheric nitrogen to ammonia. In order to be able to achieve this, Rhizobium entersinto symbiotic relationship with leguminous plants from where it receives products of photosynthesis and to which it donates ammonia which the plant uses to synthesize proteins (Dixon, 1987; Postgate, 1990). Artificial inoculation of Rhizobium into the soil therefore ensures the synthesis of proteins from atmospheric nitrogen by crops. A study carried out in Obafemi Awolowo University has revealed that some Rhizobium strains increased the yield of some legumes to between 64 and 251% [Odeyemi et al, 1982].

It has been suggested elsewhere Okafor (1994) that if nitrogen fixing bacteria could be engineered into tropical cereals and other crops, their yields would increase without the need for the current heavy expenditure on fertilizer importation. The immense fraud and racketeering involved in fertilizer importation in some African countries is probably an important factor affecting the exploitation of the Rhizobium inoculants alternative.

In Nigeria, nitrogen fixation occurs naturally on a large scale in groundnut, which was an important export crop in the 1960s. Cowpea was also widely grown during this period when Africa contributed as high as 90% of the world's cowpea production (Dobereiner and Campello, 1977). The decline in the production of these leguminous foods in Nigeria has reduced the protein intake of Nigerians where many people have been predisposed to fatal diseases as a result of malnutrition and unbalanced diets (Odeyemi and Okoronkwo, 1985).

Some microorganisms are natural pesticides. Bacillus thuringiensis for example is an aerobic spore-producing bacterium, which produces a proteinaceous crystal toxic against many insect species [Davison, 1988; Macdonald, 1989]. The fungus Collectrotrichium gloeosporioides has also been used effectively as a microbial herbicide in rice and Soya bean farming [Broerse, 1990]. Trichoderma is a commercially- produced fungal inoculants which is used to control plant diseases caused by root pathogens (Baker, 1989; Campell, 1989). The use of microbial inoculants in pest control is being encouraged worldwide because of its advantages over the use of chemicals. Some of these advantages include low cost of production low operator risk and less negative impact on the environment. One disadvantage of microbial inoculants is their sensitivity to environmental changes in the field (Broerse, 1990). For example, commercial Bacillus thuringiensis spores are inactivated rapidly by sunlight and variations in moisture and temperature in the field could affect the development, invasive ability, virulence and survival of microbial pathogens in agroecosystems (Carruthers and Haynes, 1986). As a result, special protectants and adjuvants have been formulated to prolong the residual activity of various microbial inoculants in the field [Matanmi, 1995]. In order to increase the effectiveness of biocontrol agents in the field, research and development on them is top on the priority list of international agricultural institutions. It is pertinent to stress here that research and development on microbial inoculants do not cost up to one tenth of the amount spent on chemical pesticides (Broerse, 1990).

Generally, the advantages of microbial inoculant technology, which has not been well developed in many developing countries, are better yields, lower costs and reduced dependence on agrochemicals. Most of them are not difficult to produce. According to Davison, [1988], unsophisticated fermentors of modest volume can be used to produce significant quantities of inoculants whose prospects for improved agriculture in less intensive, low-input agricultural systems are very good.

*Genetic Engineering:* The conventional system of plant breeding to produce high yielding varieties (HYVs) has now been replaced by one of the most technical and complex of biotechnological processes. It starts with DNA extraction and the location of a gene from a pant. Using synthesized antisense-RNA, the expression of this gene is blocked so as to detect its purpose when the phenotype of the pant whose gene is blocked is compared with the one whose gene is not blocked. Thus selected genes can be transferred from one organism to another to produce a desired effect. Since 1983, plant biotechnologists have recorded a high degree of success in transferring single genes that control agronomically important traits such as resistance to viruses, insects and herbicides from one plant to the other [Sasson, 1989]. Through this technique of gene transfer, it has been possible to reduce the time-span needed to develop a new plant variety from about 10-20 years to about 5-10 years (Broerse, 1990).

However, the problems with the application of this technique in developing counties are enormous. The reagents and enzymes needed are very costly and because of their unstable nature, they cannot be stored for a long time. There must be uninterrupted power supply and the laboratory must be well staffed and fully equipped (UNDP, 1989). Such laboratories are mainly located in industrialized countries.

In an overview of the application of biotechnology in developing countries, Broerse [1990] declared that genetic engineering cannot improve agricultural production in developing countries in the short term. It therefore makes sense to focus more on biotechnologies that are not too exotic and can provide short term benefits in Nigeria.

**Livestock production:** Many crop residues and agro-industrial wastes contain heavily lignified fibre, which limits digestibility by acting as a barrier to microbial utilization of cellulose and hemicellulose by microorganisms in the digestive tract of ruminants. This problem can be overcome by degrading the lignin through microbial conversion in the solid state. This biotechnological procedure is called solid state fermentation [SSF] and it has been defined as fermentation processes in which microbial growth and product formation occur on surfaces of solid substrates (Sasson, 1989). SSF is very simple biotechnological process which performs best under low moisture conditions (Mudgett, 1986). However, technical problems associated with reduction of contamination are yet to be overcome. So also is the problem of huge costs which makes it a non-profitable means of production of animal feed in a country like Nigeria where many fodder grow naturally in the savannah region where livestock rearing is widely practiced (Igboanugo and Badejo, 1998).

Another breakthrough in biotechnology applied in livestock breeding is the production of rDNA vaccines. The Deletion Mutant Vaccine for example removes the gene coding for virulence factors from the genome of a pathogenic organism using restriction enzymes. The organism then becomes non-virulent but it would still be capable of eliciting an immune response [Broerse, 1990]. Other rDNA vaccine is about US$ 5 – 10 million and this takes about 10 years! Very few developing countries can afford to invest so much money in this venture. If they do, the cost of meat will be exorbitantly high.

Another technique that has been perfected in the past two decades is Embryo Transfer Technology [ET] [Persley, 1989]. ET makes female animals produce more offspring than would be possible with normal reproduction. For example, a cow, which would normally produce four calves in a lifetime, could be made to produces up to 25. This has been successfully practiced by veterinary scientists in Asia and Latin America but the problem of huge costs still makes reliance on ET as the hope for increased livestock production in developing countries very unrealistic. The problems associated with genetic engineering in animals are more or less the same as the problems in plants. The first gene transfer was done in the mouse in 1980 and since then researchers have worked successfully on a variety of mammals, birds and fish [Persley, 1989]. Other techniques such as hormone treatment, protoplast fusion and various diagnostic tests involve sophisticated genetic manipulations. It is unlikely that application of these techniques is feasible for large-scale application in developing countries not only now but also in the future.

**Fermentation Technology:** The general definition of fermentation implies that it is the process of food spoilage by microorganisms. A more informed definition suggests that fermentation is an industrial process for the production of compounds, mostly by microorganisms in a bioreactor. In all parts of the world, plant and animal materials are fermented traditionally by various bacteria, yeast and fungi to produce foods and alcoholic beverages. In industrialized countries, these traditional fermented produce foods and alcoholic beverages have been refined and the processes have been studied to the extent that the species of microorganisms that are responsible for the fermentation process have been identified. Most of these products are now made in large factories while some are still retained in small factories in the home. Developing countries also have their own share of these products but the processes are poorly studied and the products cannot withstand competition with the imported fermented foods in the market. A list of the different sources of fermented foods in different parts of the world as well as the microorganisms responsible for the fermentation processes is presented in Table 1.

One area of research to which attention must be focused in Nigeria is in the purification of local biotechnology processes in production of alcoholic beverages. Burukutu and Pito can also be popular as other modern alcoholic beverages if the microorganisms responsible for their production are identified, isolated and cultured for mass production of the beverages. Modern biotechnology could be applied to modify the properties of organisms involved in food processing [Okafor, 1994].

**Unresolved problems in agricultural biotechnology techniques Biotechnology (Bt) crops**

The so-called ‘Bt’ crops which produce their own insecticides closely follow the pesticide paradigm, which is itself rapidly failing due to pest resistance to insecticides. Just as insects develop resistance to insecticides with time, so also do they develop resistance to the insecticide in ‘Bt’ crops with time [Alstad and Andow, 1995]. Bt crops violate the basic and widely accepted principle of “integrated pest management” (IPM), which is that reliance on any single pest management technology tends to trigger shifts in pest species or the evolution of resistance through one or more mechanisms [NRC, 1996].

**Locally Fermented and Genetically Engineered Foods**

It is observed that many developing countries have various local foods that are a product of fermentation but which unfortunately have low quality and short shelf lives. Current research efforts in the improvement of alcoholic beverages in Nigeria and other developing countries should be intensified especially in respect of purification and identification of the microorganisms responsible for each fermentation process. After all, recent evidence has shown that there are potential risks in eating food derived from genetically engineered crops as opposed to foods that products of fermentation of naturally occurring crops.

**Table 1.**
Some products of fermentation in different parts of the world. Source: Badejo and Okoh (2001).

| Source | Product | Microorganisms used | Region/Country of origin |
|---|---|---|---|
| **Dairy products** | | | |
| Milk | Yoghurt | *Lactobacillus bulgaricus* + *Streptococcus thermophilu* | Europe |
| | Cheese | *Streptococcus lactis* or *S. cremoris* | Europe (Netherlands) |
| | Swiss cheese | *Propionibacterium* spp., *Penicillium roqueforti* | Europe (Switzerland) |
| | "*Waara*" and "*Fura*" | Autochtonous microflora | Nigeria |
| **Alcoholic beverages** | | | |
| Barley + other cereals | Ale; beer | *Saccharomyces cerevisiae*, *S. carlsbergensis* | Belgium, Germany, Canada |
| Rice | Arak | not known | India, SE Asia |
| Sorghum | Kaffir beer | ,, | Malawi |
| Sweet potato | Awamori | n.i. | Japan |
| Apple juice | Cider | n.i. | U.K.; France; North America |
| Palmyra juice | Toddy | n.i. | India; SE Asia |
| Palm flower-Stalk juice | *Tuwak* | n.i. | Indonesia |
| Maize/Sorghum | "Burukutu"; "Pinto" | Autochtonous microflora | Nigeria |
| **Foods** | | | |
| Wheat and Soyabeans | *Shoyu* | *Aspergillus oryzae*; *Yeast & Lactobacillus* | Japan |
| Soyabeans | *Tempeh* | *Rhizopus oligosporus* | Indonesia |
| Soyabean curd | *Sufu* | *Actinomucor elegans* | China |
| Peanut press | *Ontjom* | | |
| Cake | | *Neurospora sitophila* | East Indies |
| Fish | Fish sauce | Halophilic bacteria | Thailand |
| Locust bean Seed | "*Iru*" (*Dawadawa*) | Autochtonous microflora | Nigeria |
| Melon | "*Ogiri*" | Autochtonous microflora | Nigeria |
| Casava | *"Gari", "Lafun", "Fufu"* | Autochtonous microflora | Nigeria |
| Maize + Other cereals | *"Ogi", "Kunnun,* "Soy-ogi" *Streptococcuslactis Saccharomyces rouxii* | *Lactobacillus plantarum,* | Nigeria |

*n.i. – no information*

It is on record that herbicide resistant soya bean contains less isoflavines, an important phytoestrogen present in the conventional soya bean. Isoflavines are believed to protect women from a number of cancers [Altieri and Rosset 1999].

At the turn of the last century, many genetically engineered foods started to flood the markets in many developing countries such as Argentina and Brazil (Lappe and Bailey, 1998). Their health effects on consumers, who are usually unaware that they are eating such food are yet to be fully investigated. Because genetically engineered [GE] food remains unlabeled, consumers cannot discriminate between, GE and non-GE food, and should serious health problems arise, it would be extremely difficult to trace them to their source. Lack of labeling also helps to shield the corporations that could be potentially responsible from liability.

**Biotechnology, hunger and the environmental question**

The notion that biotechnology is the magic bullet solution to all of agriculture's ills is not true. The claim by biotechnology companies that genetically altered seeds are essential scientific breakthroughs needed to feed the world, protect the environment and reduce poverty in developing countries has been challenged (Altieri and Rosset, 1999). The prevalence of hunger in a country has nothing to do with the size of the human population. For every densely populated and hungry nation like Bangladesh or Haiti, there is a sparsely populated and hungry nation like Brazil and Indonesia (Table 2). The world today produces more food per inhabitant than ever before. Enough food is therefore available for the world's teeming population. The real causes of food insecurity are poverty, inequality and lack of access to food. Too many people are too poor to buy the food that is available that is not evenly distributed globally. Very many people lack the land and resources to grow food themselves (Lappe, et al; 1998).

Moreover, genetically engineered plants have been planted on many millions of hectares globally without proper biosafety standards [Aitieri and Rosset, 1999]. Ecological theory predicts that the larger scale landscape homogenization with transgenic crops will exacerbate the ecological problems already associated with monoculture agriculture.

**Table 2.**
Comparison of the populations and Gross Domestic Products (GDP) of Selected Hungry Nations.

| Country | Area | | Population | | Density | | GDP (PPP) |
|---|---|---|---|---|---|---|---|
| | | | **Densely Populated** | | | | |
| **Bangladesh** | 147,570km$^2$ | 92nd | 171.7m (2016) | 8th | 1,319/km$^2$ | 10th | USD 572,440bn |
| **Haiti** | 27,750 km$^2$ | 140th | 10.6m (2015) | 85th | 382/km$^2$ | 22nd | USD 19.8bn |
| | | | **Sparsely Populated** | | | | |
| **Brazil** | 8.5mkm$^2$ | 5th | 205.3m (2015) | 5th | 23.8/ km$^2$ | 190th | USD 3.2 trillion |
| **Indonesia** | 1.9m km$^2$ | 15th | 225.4m (2015) | | 124.66/km$^2$ | 84th | USD 2.84 trillion |

Unquestioned expansion of this technology into developing countries may not be wise or desirable. There is strength in the agricultural diversity of many of these countries, and it should not be inhibited or reduced by extensive monoculture, especially when consequences of doing so results in serious social and environmental problems (Altieri et al: 1998).

The ecological risk posed by products of biotechnology has not been receiving adequate attention globally. Funds for research on environmental risk assessment are very limited. For example, the USDA spends only 1% of the funds allocated to biotechnology research on risk assessment, about $1-2 million per year. Given the current level of deployment of genetically engineered plants, such resources are not enough to even achieve adequate results. If more funds are made available for agroecologically based agricultural research, such funds would be directed towards finding lasting solutions to all the biological problems that biotechnology is trying hard to solve. More importantly, publicly controlled regulatory regimes for assessing and monitoring the environmental and social risks of biotechnology industry should be put in place so as to ensure public interest and safety, as against profit.

More food can be produced by small-scale farmers located throughout the world using agroecological technologies (Uphoff and Altieri, 1999). In fact, new rural development approaches and low-input technologies spearheaded by farmers and NGOs around the world are already making a significant contribution to food security at the household, national and regional levels in a few countries in Africa, Asia and Latin America. Yield increases are being achieved by using technology approaches that are based on agroecological principles (van der Werf, 1998a & b), that emphasize diversity, synergy, recycling and integration as well as social processes that emphasize community participation and empowerment (Rosset, 1999). When such features are optimized, yield enhancement and stability of production are achieved, as well as a series of ecological services such conservation of biodiversity, soil and water restoration and conservation, improved natural pest regulation mechanisms as highlighted by (Altieri et al., 1998).

## Conclusion

It has been demonstrated in this paper that application of modern biotechnology in agriculture is of tremendous importance in the areas of crop and livestock production as well as food processing. Specifically, biotechnological techniques such as: tissue culture, genetic engineering and solid state fermentation have their limitations in form of technical problems, high cost of operation and inability to ensure sustainability. Improvement of plant nutrition and control of pests through microbial inoculation of plants should be encouraged in developing countries due to their high prospects in increasing yield. While many countries in the temperate region are having problems with nitrogen pollution because human activities are speeding up the release of nitrogen from long-term storage in soils and organic matter, tropical soils are highly deficient in this element (Badejo, 2000). This inherent difference between temperate and tropical agroecosystems suggests that solutions to problems in temperate agroecosystems may not be applicable to tropical problems. Suggestions on how the problem of nitrogen as a limiting nutrient in the tropical moist savannah can be solved have already been proffered by (Badejo, 1998).

It is recommended that Nigeria in particular and developing countries in the tropical belt should as a matter of priority and expediency identify areas of agriculture that could be improved upon using acceptable biotechnology, such that the gains of the exercise will be affordable to the citizenry. It is the responsibility of governments of developing counties to ensure improving the quality of existing biotechnological products based on environmentally friendly agroecological principles. This of course implies that 'round pegs must be put in round holes'. A situation in which people who know nothing about biotechnology are appointed to run biotechnology agencies will certainly be counter-productive and should be avoided. Government should also ensure that appropriate legislations are put in place to compel the industrial sectors to utilize the products of sustainable biotechnology research in developing countries and de-emphasize the continuous importation of materials for which there are alternatives at home.

According to Ojo and Adebayo (2012), " …Food is an essential component of welfarism. In order to avoid recapitulation, public policy makers must as a matter of urgency should see food as a component of welfarism and as such develop sufficient political will to achieve increased food production, evolve sustainable food policy and eventually attain food security for all. …Any government that makes her citizens go hungry will definitely run into trouble."

Moreover, Nigeria and other developing countries should as a matter of priority and expediency identify other areas of appropriate biotechnology that could be improved upon to be synergistic with sustainable biotechnology so that the gains of the exercise will be affordable to the present citizenry as well as future generations. A sustainable agricultural system must be ecologically sound, economically viable, and socially responsible. These three dimensions of sustainability are inseparable, and thus, are equally critical to food security on the long run.

**REFERENCES**

Adeoti, J.A. (1989), "Economic Crisis in Developing Countries: The Food Dimension", Ilorin Journal of Business and Social Sciences, Vol. 1.

Akinyele, Isaac (2010). Ensuring food and nutrition security in Rural Nigeria: An assessment of the challenges, information needs, and analytical capacity. Nigeria Strategy Support Program, IFPRI, Brief No 18.

Alstad, D. N. and D. A. Andow, 1995. Managing the Evolution of Insect Resistance to Transgenic Plant. Science 268, 1894-1896.

Altieri, M. A., P. Rosset, and L. A. Thrupp, 1998. The potential of agroecology to combat hunger in the developing world, 2020 Bried 55. International food policy research institute. Washington DC.

Altieri, M. A. and P. Rosset, 1999. Ten reasons why biotechnology will not ensure food security, protect the environment and reduce poverty in the developing world. [unpublished].

Attah, Ademu Wada (2012). Food Security in Nigeria: The Role of Peasant Farmers in Nigeria African Research Review, Vol. 6 (4), Serial No. 27, pp.173-190.

Badejo, M. A., 1998. Agroecological restoration of savannah ecosystems. Agric. Engr. 10: 209-219.

Badejo, M. A., 2000. Obstacles to the achievement of sustainability in the industrial and agricultural sector. In: Kobiowu et al. (eds). Book of Readings on Education, Environment and Sustainable National Development. pp. 84-103.

Badejo M.A. and A.I. Okoh (2001) Problems of application of modern biotechnology in agriculture in developing countries. Journal of Agricultural Engineering and Technology, 9: 1-12Baker, R., 1989. Improved Trichoderma spp. For promoting crop productivity. Trends in Biotechnology, Vol. 7, February 1989, pp. 34-38.

Badejo, 'Tola (2011). Technology Transfer and Agricultural Production. 7th Annual Lecture, School of Agriculture and Agricultural Technology. Friday 2nd December, 2011.

Bello, A. (2004), Keynote Address presented by the Honourable Minister for Agriculture and Rural Development, at the ARMTI Annual Lecture, Ilorin, March 24, 2004.

Broerse, J.E.W., 1990. Agricultural Biotechnology. Lecture notes for Environmental Science and Technology Students, IHE, The Netherlands, pp. 20.

Campbell, R., 1989. The use of microbial inoculants in the biological control of plant diseases In: Microbial Inoculation of Crop Plants, edited by R. Campbell and R. M. Macdonald. Special publications of the Society for General Microbiology, Vol. 25, IRL Press, Oxford, England. pp. 67-77.

Clover, J. (2003), Food Security in Sub-saharan Africa, African Security Review, Vol. 12, No.1.

Davison, J., 1988. Plant-Beneficial Bacteria. Biotechnol., Vol. 6, March 1988, pp. 282-286.

Dixon, B., 1987. The Gene Revolution. The UNESCO Courier, March 1987, pp. 13-16.

Dobereiner, J. and A. B. Campello, 1977. Importance of legumes and their contribution to tropical agriculture. In: A treatise on dinitrogen fixation. F. Hardy and A. H. Gibson. (eds) John Wiley & Sons, New York.

FAO (1996). Socio-Political and Economic Environment for Food Security, Food and Agriculture Organization of the United Nations, World Food Summit, Vol. 1, Sec. 1.4.

Idachaba, F. (2004), "Food Security in Nigeria Challenges under Democratic Dispensation", paper presented at ARMTI, Ilorin, Kwara State (March 24, 2004).

Igboanugo, A. B. I. and M. A. Badejo, 1998: Solving the problem of productivity and land use in the semi-arid tropics. In: Badejo M. A. and A. O. Togun. Strategies and Tactics of Sustainable Agriculture in the Tropics College Press, Ibadan & Enproct Consultants, Lagos. pp. 149-169.

Lappe, M. and B. Bailey, 1998. Against the grain: biotechnology and the corporate takeover of food. Common Courage Press, Monroe, Maine.

Lubberding, H. J., 1990. Introduction to Biotechnology. Lecture notes for Environmental Science and Technology Students, IHE, The Netherlands, pp 43.

Macdonald, R. M., 1989. An Overview of Crop Inoculation. In: Microbial Inoculation of Crop Plants edited by R. Campbell and R. M. Macdonald. Special publications of the Society for General Microbiology, Vol. 25, IPL Press, Oxford, England. pp. 1-9.

Matanmi, B. A., 1995. Biocontrol agents and the environmental question. In: Insects and the Nigerian Environment, edited by I. I. Uvah and M. A. Badejo Ent. Soc. Nig. Occ. Publ. No 30, 1995.

Mudgett, R. E., 1986. Solid State Fermentation. In: Manual of Industrial Microbiology and Biotechnology, edited by A. L. Demain and N. A. Solomon, Washington, 1986, pp. 66-83.

National Research Council (NRC) (1996) Ecologically Based Pest Management. National Academy of Sciences, Washington DC.

Odeyemi, O., M. O. Fifi, and A. Abiola, 1982. An investigation of possible cross-inoculation among some strains of cowpea Rhizobium and different cowpea group cultivars. Turrialba, 32:161-167.

Odeyemi, O. and N. Okoronkwo, 1985. The Suitability of local materials as carriers for rhizobia in legume inoculants production in Nigeria. In: Biological Nitrogen Fixation in Africa. Eds Ssali, H. and S. O. Keye. African Association for Biological Nitrogen Fixation, Nairobi, Kenya, pp. 135-150.

Okafor, N. 1994. Biotechnology and Sustainable development in Sub-Saharan Africa. World. J. Microbiol. Biotech., 10:243-248.

Ojo, E. O. and Adebayo, P. F. (2012) Food security in Nigeria: An overview. European Journal of Sustainable Development. 1,2: 199 – 222.

Omonona, Bolarin Titus and Agoi, Grace Adetokunbo (2007). An analysis of food security situation among Nigerian urban households: Evidence from Lagos state, Nigeria. Journal of Central European Agriculture. Volume 8 No. 3 (397-406).

Persely, G. 1989. Agricultural Biotechnology: Opportunities for International Development. Synthesis report of the Biotechnology Study Project Papers, World Bank, International Service for National Agricultural Research (ISNAR), Australian Centre for International Agricultural Research (AIDAB) and Australian International Development Assistance Bureau (ACIAR).

Postgate, J., 1990. Fixing the nitrogen fixers. New Scientist, 3 February, 1990, pp. 57-61.

Rentlinger, S. (1983), "Food Security and Poverty in LDCS", Finance and Development, Vol. 22, Nos. 7-11.

Roskoski, J. P., 1992. Biological nitrogen fixation (BNF): commonly asked questions and answers. World J. Microbiol. Biotech., 8:337-339.

Rosset, P. 1999. The multiple functions and benefits of small farm agriculture in the context of global trade negotiations. Institute for Food and Development Policy, Food First Policy Brief No. 4.

Sasson, A., 1989. Biotechnologies and Developing Countries: Present and Future: Information document and basis for a keynote address to the FAO/CTA Symposium on "plant Biotechnology for Development Countries", Luxembourg, 26-30 June 1989.

UNDP, 1989. Plant Biotechnology including Tissue Culture and Cell Culture. UNDP programme Advisory Note, New York, July 1989.

Uphoff, N. And M. A. Altieri, 1999. Alternatives to conventional modern agriculture for meeting world food needs in the next century. Report of a Bellagio Conference. Cornell International Institute for Food, Agriculture and Development. Ithaca, New York.

van der Werf, E., 1998a. Sustainable agriculture in southeast Ghana: A case study of the Agomeda project. In: Badejo M. A. and A. O. Togun. Strategies and Tactics of Sustainable Agriculture in the Tropics. College Press, Ibadan & Enproct Consultants, Lagos. pp. 170-195.

World Bank (1986). Poverty and Hunger; Issues and option for food security in developing countries. A World Bank policy study, Washington