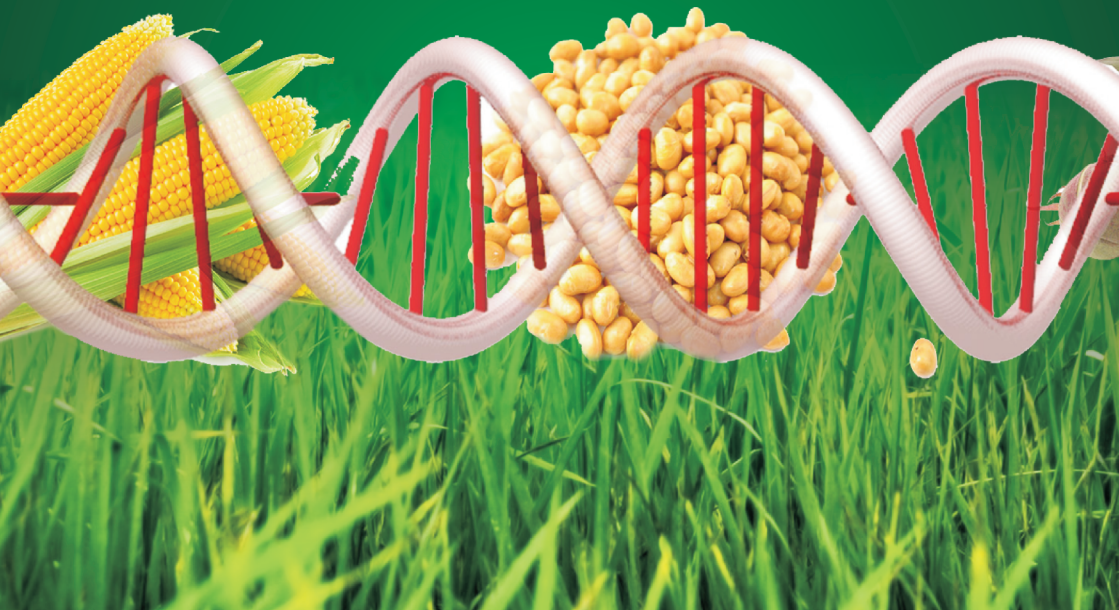
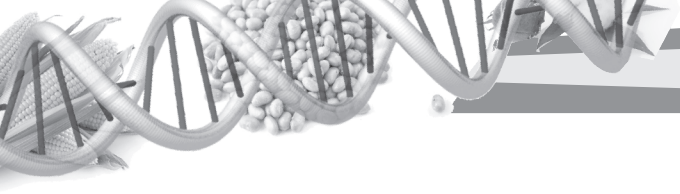
THE NIGERIAN ACADEMY OF SCIENCE

GENETICALLY MODIFIED ORGANISMS (GMOs) IN NIGERIA: FACTS AND FICTION

Summary of the GMO Stakeholders' Roundtable





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The Nigerian Academy of Science

The Nigerian Academy of Science (NAS) is the foremost independent scientific body in Nigeria which was established in 1977 and incorporated in 1986. NAS is uniquely positioned to bring scientific knowledge to bear on the policies/strategic direction of the country and is also dedicated to the development and advancement of Science, Technology, and Innovation (STI) in Nigeria. The aims and objectives of the Academy are to promote the growth, acquisition, and dissemination of scientific knowledge and to facilitate its use in solving major problems of national interest. The Academy strives to do this by:

- Providing advice on specific problems of scientific or technological nature presented to it by the government and its agencies, as well as private organizations
- Bringing to the attention of the government and its agencies problems of national interest that science and technology can help to solve
- Establishing and maintaining the highest standards of scientific endeavour and achievement in Nigeria, through the publication of journals, organization of conferences, seminars, workshops, and symposia, recognition of outstanding contributions to science in Nigeria, and the development of a working relationship with other national and international scientific bodies and academies

As with national academies in other countries, NAS is a national not-for-profit organization with membership comprising 222 Fellows elected through a highly competitive process who have distinguished themselves in

their fields both locally and internationally. Some of its members have served as Vice-Chancellors of universities, Directors-General of government parastatals, and Ministers in federal ministries. The Academy, given its clout, also has the ability to attract other experts from around the country and internationally when needed. NAS is Nigeria's national representative on such bodies as the International Council for Science (ICSU) - the umbrella body for all science associations and unions, and the Inter-Academy Panel (IAP) - the umbrella body for all national science academies globally. The Academy is also a member of the Executive Committees of the Inter-Academy Panel for Research (IAP-R) and the Network of African Science Academies (NASAC).

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Preface

The application, commercialization, and regulation of Genetically Modified Organisms (GMOs) are some of the most highly debated issues globally. These organisms have several potential applications, most significantly in agriculture, medicine, industry, and environmental matters. However, despite the seeming benefits to be derived from the use of GMOs, there is resistance to efforts to fully embrace them. Apparent drawbacks include possible loss of biodiversity, unintended negative impact on animal and human health, elimination of non-target species, and destruction or disruption of ecosystems. In Africa where 60% of the population are farmers, and ensuring food security is an ongoing concern, many see the introduction of GMOs as the way forward. Nigeria has not been left out of the GMOs revolution. Nigeria is yet to fully embrace the relevant technologies that have been associated with global developments with GMOs revolution. However in 2015, the National Biosafety Management Act was enacted into law to regulate the use of biotechnology and GMOs in Nigeria.

As part of its mandate, the Nigerian Academy of Science (NAS) seeks to engage relevant stakeholders on issues of national interest and provide evidence-based advice for policy making. Given that the adoption of GMOs by Nigeria is not just a scientific issue; but one with economical, social, and ethical ramifications, it is necessary that all stakeholders be engaged in the GMO debate. To this end, NAS, in collaboration with the National Biotechnology Development Agency (NABDA), convened a one day stakeholders' roundtable focused on GMOs in Nigeria on Tuesday, November 15th, 2016 in Lagos. In attendance

were scientists, representatives of industries, officials from relevant government agencies, as well as fellows of the Academy. The objectives of the roundtable were to raise awareness on issues related to GMOs, their use, and regulation in Nigeria; discuss the evidence on GMOs - the merits and demerits; and foster collaboration/ communication between relevant stakeholders.

This report outlines the presentations and discussions during the roundtable and is intended for all stakeholders in scientific and national development in Nigeria.

GMOS IN NIGERIA- LEGISLATION, GOVERNANCE, AND POTENTIAL BENEFITS

Overview of GMOs

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Genetic modification is a means of transferring genes from one biological source to another. It is a deliberate attempt that allows the recombination of genes of a host organism that serves as an expression host which is then said to be genetically modified, enhanced, or improved. The universal nature of genetic codes makes it possible for genes to be transferable and functional in organisms other than that from which they are derived. Organisms (agricultural crops, animals, or microbes) that have been altered in such a manner are referred to as GMOs. Through genetic engineering, man can increase the productivity and growth rate of livestock, animal products, and crops, or even the yield of antibiotics produced by bacteria and fungi. Genetic modification enables the production of resilient crops which are resistant to pesticides and are selectively toxic to insects. GMO technology is not just limited to foods; but also has applications in industry. For example, Bt- cotton farming could resuscitate the textile industry in Nigeria, in the long run creating much needed new employment opportunities.

A much touted point against GMOs is the ban on them by some European countries. However, it should be noted that European countries are not as populated as Nigeria is and

are, as such, not plagued with the same food security issues. Further claims that GMOs may have adverse health effects on man are currently unfounded. Genetic modification experiments are usually conducted under strict surveillance to ensure compliance with the safety guidelines and efficient management of unintended risks associated with the technology.

Embracing modern biotechnology would serve as a way of getting Nigeria out of the brink of joblessness,economic hardship, technological backwardness, and food insecurity. Solutions to malnutrition, disease burden, effective pollution control, as well as food and drug manufacturing lie in the adoption of GMOs. GMO technology would be important in achieving key items on the Nigerian government's agenda including the school feeding programme, revamping the agricultural sector value chain, the Ogoni clean up, as well as the prevention of threatening infectious diseases.

Unveiling Molecular Techniques in GMOs: The Implication for Public Health and Safety

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GMOs are organisms in which the genetic material has been altered in a way that does not occur naturally by mating or natural recombination. The first example of this occurred in 1978 when Herbert Boyer, took a version of the human insulin gene and inserted into the bacterium Escherichia coli to produce synthetic "human" insulin. GMOs are produced through various techniques including genetic modification, modern biotechnology, genetic engineering, gene technology, recombinant deoxyribonucleic acid (DNA) technology, gene slicing, and transgenesis. These methods allow for the manipulation of the DNA (the molecule that carries the genetic information in all cellular forms of life and some viruses)of cells to produce biological products or to change hereditary traits.

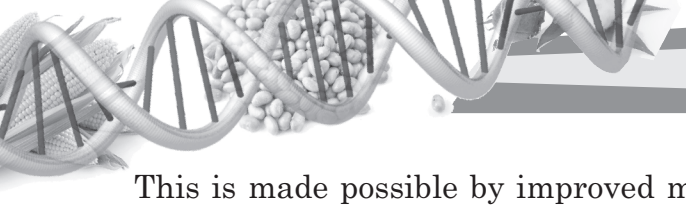
Altering genetic trait is an act of creativity; it involves mathematical modelling, empirical evidence, as well as scientific, economic, social, and practical knowledge. New genetic materials are produced by the insertion of nucleic acid molecules into a virus, plasmid, or other vector system. The genetic product is then incorporated in to a host organism in which it does not naturally occur but in which it is capable of continued propagation.

GMOs have a wide scope of applications in medicine. Bacteria and donor fragments are used to produce large

quantities of biomedical products (hormones, growth factors, antibodies, interferons, antibiotics, probiotics, vitamins, and vaccines). Therefore as a result ofthis technology there is increased availability ofmedically important products for disease management and infection control. GMOs are also important in the agricultural and industrial sectors, offeringadvantages over traditional methods. GMOs can beused to increase molecular diversity, improve chemical selectivity, as well as sufficient, cheaper, and safer supplies of desired products. Also, GMOs are beneficial to the environment; they can be used for weed control, decontamination of toxic waste sites, and reduction in the use of pesticides and toxic chemicals. Furthermore, GMOs offer opportunities to improve the quality and quantity of food available for consumption,by increasing farm yields and profitability through reduced costs and new product varieties.

Conversely, the main areas of concern for human health in the use of genetically modified microorganisms (GMMs), genetically modified food (GMF), or genetically modified products (GMPs) are allergenicity, gene transfer, and out-crossing. Issues of laboratory procedures and safety are also of concern particularly exposure to potentially toxic reagents and chemicals, radiation from ultra violet (UV) lights, management of waste from GMO laboratories, and the likelihood of laboratory exposures to GMOs.

Presently in Nigeria, there are no commercially available GMFs, though trials are ongoing. In countries where GMOs are accepted, their safety is continuously tested.



This is made possible by improved molecular techniques backed with corresponding sophisticated equipment, personnel, and policies. With the future prospect of commercial GMFs in Nigeria, there should be an assessment of the country's capacity to continually monitor the effect of consuming these products. Going forward, Nigeria should ensure standard ways of providing information on safe or prohibited products and approved processes, maintain peaceful coalition between stakeholders in public health and relevant industries, conduct safety assessment of GMOs according to the Codex Alimentarius Commission (CAC) guidelines, implement formulated policies, and ensure adequate regulation for the consumption and use of imported GMPs.

GMOs in Nigeria

Dr. Rufus Ebegba
Director General, National Biosafety Management Agency (NBMA)

The world today faces a myriad of challenges: growing population, increased consumption of food, feed, fibre, and fuel, loss of agricultural land, shortage of water for irrigation, climate change, increasing demand for renewable fuels, reduced agro biodiversity, loss of natural habitats and biodiversity, diseases and health concerns, unemployment, as well as terrorism. These challenges have necessitated the adoption of new technologies including biotechnology. Modern biotechnology involves the fusion of cells beyond their taxonomic family to overcome natural physiological, reproductive, or recombination barriers using techniques outside of traditional breeding and selection. It entails the selection and transfer of desirable traits in living things to related or unrelated species to achieve desired purposes. This technology is applied in the fields of agriculture, medicine, industry, and environmental sustainability. GMOs are the products of modern biotechnology, and could be plants, animals, or micro-organisms in which DNA has been transformed. These organisms contain desired specific genes from unrelated or related species and exhibit a particular/desired trait in the recipient organism.

New technologies often offer great potentials but they also need to be adequately regulated in order to ensure that they are safe and sustainable. There is no 'zero risk' in life, therefore modern biotechnology and GMOs are not

insulated from potential risks regardless of their potential benefits. The GMF debate has no foreseeable resolution and there may not be a unilateral answer to this debate. This debate is global, impacting all societies regardless of their socioeconomic status. The major concerns of those who oppose GMFs include the risk of allergenicity and toxicity in humans, and the potential negative environmental effects of modified crops. This is notwithstanding the extensive tests on GMFs for allergenicity, toxicity, and environmental safety.

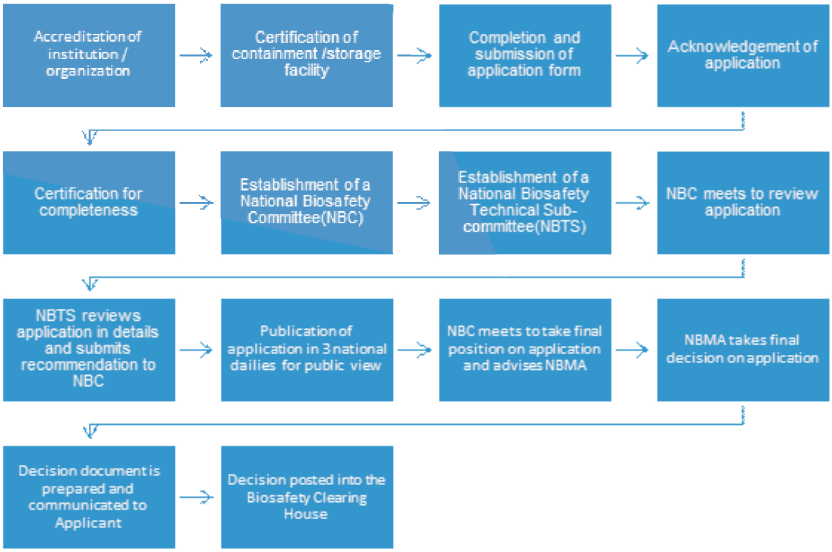
Nigeria is endowed with a variety of plant and animal species, which require conservation and sustainable utilization in the face of modern biotechnology. The Cartagena Protocol on Biosafety (CPB) provides international safety rules for the adoption of modern biotechnology and the handling and use of Living Modified Organisms (LMOs) to ensure an adequate level of protection for the conservation of biological diversity taking into account risks to human health. Nigeria has adopted modern biotechnology as one of the tools for addressing challenges that have been difficult to resolve using conventional breeding processes. The country has signed and ratified the CPB as a commitment to global biosafety and it has been domesticated it through an act the National Biosafety Management Act-which was passed in 2015.

This process commenced in 2002 with the constitution of a multi-stakeholder national committee which went round the six geo-political zones of the country. Thereafter, the National Biosafety Bill went to the National Assembly in

2008 and was initially passed in 2011 but was not assented to. The bill went back to the National Assembly in 2013 and was subsequently passed in 2015. Public hearings were part of the processes adopted by the National Assembly in the passage of the bill. The Biosafety Act provides a framework for risk assessment and risk management; offences, penalties and enforcement; liability and redress; as well as regulations to safeguard human and environmental health from potential adverse effects of GMOs and ensure safety in the practice of modern biotechnology. The Act established the National Biotechnology Management Agency (NBMA) which is charged with the responsibility of providinga regulatory framework as well as the institutional and administrative mechanisms for safety measures in the application of modern biotechnology in Nigeria with the view to prevent any adverse effect on human health, animals, plants, and environment. Other objectives of the NBMA are to provide measures for effective public participation and awareness of modern biotechnology and GMOs, ensure that the use of GMOs does not have any adverse impact on socio-economic and cultural interests either at the community or national level, and capacity building of its personnel.

There are existing policies, frameworks, and institutions that support the adoption of modern biotechnology in Nigeria. These include an agricultural policy, a biotechnology policy, private biotechnology concerns, and the National Biosafety Management Agency Act. There are also accredited research institutes for modern biotechnology including the National Root Crops Research Institute (NRCRI), Umudike; Institute for Agricultural

Research (IAR), Samaru; Federal University of Technology Akure (FUTA); National Cereals Research Institute (NCRI), Badeggi; and NABDA. Confined field trials have been conducted on bio-fortified cassava enhanced with pro-Vitamin A, bio-fortified cassava enhanced with iron, and Genetically Modified (GM) Cassava resistant to Cassava Mosaic Virus and Brown Streak Virus. Confined field trials on Cowpea modified for resistance against Maruca insect pest are currently at the multi-locational level. Trials on Africa Biofortified Sorghum with increased bioavailability of iron, zinc, protein, and pro-Vitamin A are ongoing while those on GM rice modified for Nitrogen-use efficiency, water-use efficiency, and salt tolerance have just commenced.



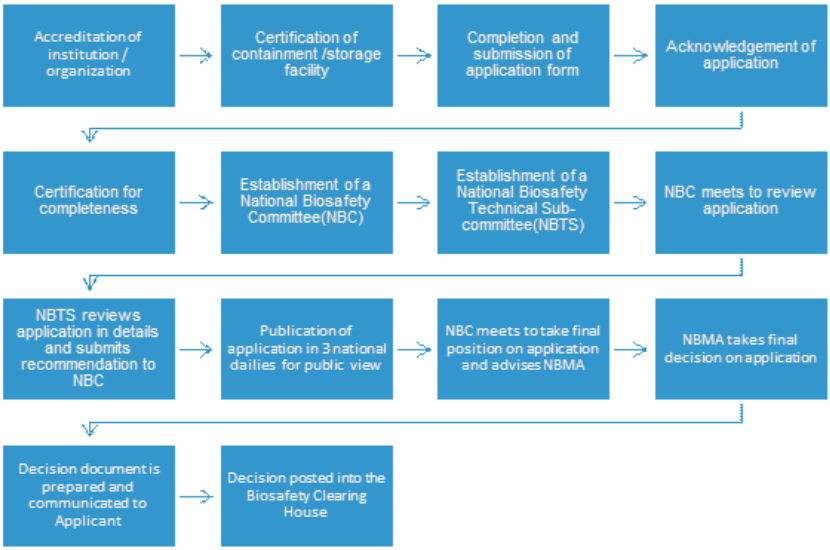


Figure - Biosafety Application Process in Nigeria

Safety in modern biotechnology practice and the use of GMOs is not negotiable. The NBMA is well positioned to effectively manage and ensure safety in the application of modern biotechnology and the use of GMOs in Nigeria (Figure 1). Relevant stakeholders are advised to play by the rules as any breach of the National Biosafety Management Agency Act 2015 and other pursuant regulations have severe consequences. The global debate on the environmental and health safety issues surrounding GMOs is getting louder; the voices of those against the technology are loud while those for the technology are not heard enough. There is a need for a mechanism to allay unfounded fears. Scientists and other proponents of modern biotechnology and GMOs must make conscious effort to enlighten the public while regulators should have the courage to regulate and create confidence in the minds of the public. The public must trust government's position in the regulation of modern biotechnology and GMOs. The position of international bodies like the WHO and the Food and Agricultural Organization (FAO) should guide the acceptability of GMOs, and the position of academies of science should be based on scientific evidence to ensure public confidence.

Developing Transgenic Crops: the Brazilian Success Stories

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Brazil is the second largest producer of GM crops, second only to the United States. The success stories of transgenic crops in Brazil are firmly rooted in science and technology, driven by stakeholders, resulting in development and commercialization. The first Brazilian biosafety law dates back to January 1995. That law was repealed and a new biosafety law was instituted in 2005 which regulates the use of GMOs, set safety standards and established oversight and regulatory institutions.

Since the adoption of the new legal framework, the number of approved events in Brazil relating to GM crops has been steadily on the increase. Currently, there are approved variants of GM corn, cotton, soybeans, beans, vaccines, and microorganisms. Additionally GM eucalyptus was approved for use in Brazil in 2015. Insertion of a new gene reduces the time between planting and harvesting for this plant, hence the trees spend less time on land. Also, the transgenic eucalyptus yields 20% more cellulose because its trunk is wider than the traditional variant. Embrapa/BASF Cultivance® Soybean and Imidazolinone tolerant soybean which are tolerant to herbicides have also been introduced commercially, and insect-resistant and folate-fortified lettuce are also available. A strain of *Aedes aegypti* (OX513A) was developed in 2014 which expresses a self-limiting transgene that prevents larvae from developing to adulthood

and Brazil was the first country to approve the unconstrained release of these GM mosquitoes[1].

There has been research collaboration between scientists from the Brazilian Agricultural Research Corporation (Embrapa)'s National Centre for Genetic Resources and Biotechnology(CENARGEN) and scientists from the Ahmadu Bello University (ABU) Zaria, to develop virus-resistant cowpea variants, resistant to cowpea aphid-borne mosaic virus (CABMVI) and cowpea severe mosaic virus (CPSMV) using the technique of ribonucleic acid (RNA) interference. This collaboration generated seven cowpea lines which presented with milder symptoms when compared to control and three lines which presented enhanced resistance to both viruses. Beyond the production of these modified cowpea lines, the project also facilitated capacity building amongst the scientific community of ABU, and there is the potential for future collaborations. Undergraduate and postgraduate students from ABU were trained on embryo excision, morphological characterization of cowpea meristem, and RNA manipulation from leaves for detection of viruses. Also, five researchers from ABU were trained on genetic transformation of cowpea in Brazil. A cowpea transformation system comprising of a particle delivery system developed by Embrapa was installed in ABU making it the first of its kind in Nigeria.

[1] de Andrade PP et al. (2016). Use of transgenic Aedesaegypti in Brazil: risk perception and assessment. Bulletin of the World Health Organization. Article ID: BLT.16.173377

Audience reflections

- *The public needs to know that areas of concern regarding the use of GMOs can be addressed, this will make them less anxious about this issue*
- *This forum is important. Biotechnology is new in Nigeria so we must learn from other countries. We must not lose out of the gene revolution like we have lost out of others. Today is a day of accountability. We as stakeholders need to speak out. GM crops have been around for over 20 years. What is Nigeria afraid of? Responsible biotechnology will take the country to the next level. Biotechnology is not a panacea but it can significantly contribute to agricultural development*
- *Universities' curricula and students should be carried along in Nigeria's GMO journey. Especially as some might not be aware of the modalities and certifications needed to carry out GMO research in the country*
- *It is important to note that GMOs are not intended to take over conventional agriculture and health practises. They are intended to be complementary to these*
- *It might be difficult to have responsible biotechnology in Nigeria if there is no enabling environment for this. There is inadequate infrastructure for regulation; and the confidence of the general public will rely heavily on this. Structures and setups should be put in place*

- *Applications of GMOs need to be promoted in Nigeria however legislative processes have not been firmly put in place. However, we seem not to be equipped for legislation Stakeholders have not been fully engaged in the process and public awareness is low*
- *The establishment of the NBMA is a 15-year process; the necessary infrastructure and expertise are in place. It is noteworthy that the highest qualification in biosafety is an M.Sc.; NBMA has 5 personnel with this qualification. The NBMA has what it takes to effectively manage biosafety in Nigeria and efforts have been made to sensitize and carry stakeholders along. Furthermore the NBMA functions separately from NABDA. To ensure neutrality, regulators have to be different from the promoter*
- *Biotechnology on its own cannot be irresponsible, that depends on the user. When biotechnology is used with malicious intent, that can be said to be irresponsible, and this should not be allowed in Nigeria*
- *In the case of imported processed products that contain GMOs, accreditation and approval should be gotten from the NBMA*
- *The government has given the NBMA the political will to conduct its activities; there should therefore be no fears of interference in that regard*
- *With regards to the concern that proteins from GMOs and their products may be transferred to humans, it is important to note that these*

proteins are usually destroyed in the processing of GMPs. Additionally, the human body is capable of processing these proteins. In all likelihood we have already been exposed to GMOs

- *We need to revitalize our local industries and GMOs will help in accomplishing this.*
- *Awareness creation is key and should be strengthened. There should be engagement with key ministries and agencies. Issues of doubt can be dispelled through Information, Education, and Communication (IEC) materials.*
- *We should not overlook the issue of the safety of laboratory workers. Capacity building of biotechnologists on safety is important*
- *There is the need to develop simple methods for quality control; for example GMO identification tests that are simple to conduct*
- *All commercially available GMOs should be labelled. The major constraint would be the Nigeria's highly porous border as the Act is not likely to prescribe for this*
- *The ban of GMOs in Europe relates to their cultivation; GMOs are readily consumed in Europe*
- *Looking at the situation in Brazil, it is clear that a conducive environment for biotechnology must be created to achieve any meaningful success. Furthermore, Nigeria should be needs-focused*
- *Nigeria should invest in science and technology particularly consistent and adequate research funding in biotechnology*

POTENTIAL IMPACTS AND BENEFITS OF GMOS ON CRITICAL SECTORS IN NIGERIA

Potential Impacts and Benefits of GMOs

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A GMO is an organism whose genome has been altered by the techniques of genetic engineering so that its DNA contains one or more genes not normally found therein. Commercially available GMFs include plant crops such as canola, maize, cotton, soybean, sugar beet, papaya, alfalfa, and squash. There are also examples of GM animal foods. The Enviropig or Frankenswine are a line of GM pigs that have been enhanced with murine and *E coli* DNA to enable better processing and digestion of phosphorus making it unnecessary to feed them with additional phosphorus. These GMOs were introduced to address the high levels of phosphorus found in the manure from standard pigs. When this manure is used as fertilizer, phosphorus gets into the water, leading to algae blooms, oxygen depletion, as well as death of marine life. The Enviropig doesn't need to be fed with additional phosphorus, so their manure has quite low level of it, thus it does not have to cause the same negative effects. AquaBounty made their contribution to the world's GM animals in the form of a fast-growing salmon. This fish grows twice as fast as the typical fish, with the same odour, colour, texture, and flavour of standard salmon. These Atlantic salmon were genetically engineered to add the growth hormone of Chinook salmon so they can produce

the necessary growth hormone throughout the entire year. The hormone stays activated by a gene from the Ocean pout. There are still debates, however, as to whether this fish is safe to eat. Cows produce high methane, which is the second largest factor for greenhouse effect, due to their digestion process. Agriculture research scientists from the University of Alberta worked to identify the bacterium that is responsible for the methane production. Afterwards, they created cattle with 25 % less production of methane compared to average cows. Tilapia has undergone genetic modifications to let them mature much faster, survive on a smaller quantity of food, and grow larger. Tilapia farmers, however, want to take this a step further and make male tilapia more common than female ones. Females "mouthbrood" (hold eggs in their mouths for a period of time and do not eat) resulting in small size. Tilapia farmers prefer males on their farms. Scientists in Israel have made featherless chickens which are cheaper to raise, more environmentally friendly, and don't require plucking, hence saving time[2]. The scientists say they bred a species which has naked neck with a standard broiler chicken. There are, however, some drawbacks. The feathers on chickens help protect them from harsh weather, parasites, and overzealous cocks during mating.

In the agricultural sector, especially in crop production, GMOs can be of potentially significant impact. GMOs can lead to an increase in food and agricultural production[3] by accelerating the selection and transfer of desirable traits,

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[2] Genetically modified animals. http://www.enkivillage.com/genetically-modified-animals.html

[3] Brookes, G. 2014. What are the real economic and environmental impacts of GM crop use? https://gmoanswers.com/studies/what-are-real-economic-and-environmental-impacts-gm-crop-use

eliminating sexual incompatibility between plant species, increasing the size of available gene pool, and engineering resistance to abiotic and biotic stresses such as drought, extreme temperature, salinity, insects, pathogens, etc. The use of GMOs in agriculture could also improve productivity by using less land for cultivation, enhance soil quality and reduce the levels of soil erosion, increase water retention, reduce the levels of nutrient runoff, as well as increase tolerance to specific herbicides. Despite these benefits, there are also challenges such as the emergence of weeds resistant to herbicides like glyphosate with a resultant increase in herbicide use.

In the industrial and technological sectors, there are potentials for longer shelf life for fruits and vegetables through genesilencing, the production of potatoes of high amylopectin starch for the textile and other industries, as well as plastics and biofuels manufacture. GMOs can also be of potential benefit to the environment by the reduction in water pollution problems, decrease in the amount of insecticides and herbicides applied to the GM crops, decrease in global green house gas (GHG) emissions, and reductions in fuel use[4]. However, there are concerns of the environmental challenges of GMOs including the possible disturbance of the ecosystem, possible release of toxins into the environment and adverse effect on the food chain.

[4] Brookes, G. and Barfoot, P. (2013). Key environmental impacts of global genetically modified (GM) crop use 1996 - 2011. GM Crops and Food 4 (2): 109 - 119. DOI:10.4161/gmcr.24459

Table - Advantages, Technological and Utilitarian Features of GMFs

Food	Benefits from genetic modifications
Rice	Higher content of β carotene Higher iron bioavailability
Tomato	Higher content of dry matter Delayed ripening process Aroma intensification Virus resistance
Potato	Higher amylopectin content Cyclodextrin production Resistance to viruses and potato beetle Lower alkaloids content
Milk (cow, goat, sheep)	Increased tolerance for high temperature Modifiedcaseincontent Lower lactose content
Transgenic fishes (carp, salmon, trout)	Faster growth rate

Source: Kramkowska et al. (2013)[5]

GMOs have found varying applications in addressing global health challenges. A.aegypti mosquitoes have been modified to transmit a gene to their offspring that causes the offspring to die before becoming sexually mature. Furthermore, new treatment options have emerged including gene therapy for diseases such as metabolic disorders and cancers. GM technology has also been applied to the production of pharmaceuticals from plants as well as the development of concentrated sources of nutraceuticals and human Intrinsic Factor[6,7]. Potential challenges in this sector include the effect of toxins on the viability of human cells, potential release of genetically altered DNA in human digestive tract, infertility, immune

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5 Kramkowska, M., Grzelak, T. and Czyzewska, K. (2013). Benefits and risks associated with genetically modified food products. Annals of Agricultural and Environmental Medicine 20 (3): 413 - 419.

6 IUCN (2007).Current knowledge of the impacts of genetically modified organisms on biodiversity and human health. An Information Paper.The World Conservation Union, pp 1- 53. http://cmsdata.iucn.org/downloads/ip_gmo_09_2007_1_.pdf

7 Key, S., Ma, J. K. C. and Drake, P. M.W (2008).Genetically modified plants and human health. Journal of the Royal Society of Medicine 101 (6): 290 - 298.

dysregulation of gene, increase in food allergies, antibiotic resistance, and decreased nutritional value.[8]

Aside from the challenges facing the use of GMOs on the various critical sectors, there are also other challenges within the Nigerian context including the dependence on imported industrial raw materials and processed foods, highly porous borders with little control and monitoring, and dependence on food aids. Also, the outcome of research and development of GM crops has not been widely reported. There is a need for detailed studies on performance evaluation of GMOs under Nigerian agricultural practices, characteristics of GMOs produced in the Nigerian environment, as well as evaluation during processing of GMF plant materials in the manufacture of Nigerian foods and beverages. Studies on risk assessment and environmental impacts, safety and health implications, and economic implications are also necessary. Going forward, there is a need for the monitoring of raw and processed food and agricultural materials (imported and locally produced) for GM content, awareness and inputs into government legislation, empowerment of the NBMA for continuous and active implementation of the 2015 Act, and enforcement of research funding by private companies interested in GMO production.

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[8] Verma, C., Nanda, S., Singh, R. B. and Mishra, S. (2011). A review on impacts of genetically modified food on human health. The Open Nutraceutics Journal 4: 3 - 11.

Audience reflections

- *GMOs can have positive impact in Nigeria's health and agricultural sectors. This impact includes job creation, creation of planting materials, improvement of the life span of perishable goods, improved nutrition and economy, and the production of health products*
- *The capacity to monitor GMOs is important. Nigeria should be prepared for this undertaking*
- *GMOs will also increase access to medicines, improve health, and reduce the prevalence of non-communicable diseases. GMOs will also be relevant in disease control and help to increase life expectancy*
- *The NBMA and NABDA must engage all relevant stakeholders including Customs and Immigration in the monitoring of GMPs*
- *There is a need to strengthen the capacity of existing agencies. Funding is key; advocacy on this, to sensitize the government, is necessary*
- *Nigeria wants to take advantage of GMOs but we are not ready*
- *Nigerian farmers are ready to support the introduction of GMOs. However there are concerns about the prevailing myths. Scientists should disabuse stakeholders of these myths*

AREAS OF CONCERN REGARDING GMO USE IN NIGERIA

GMOs in Nigeria: Facts and Fiction

Professor Oyebiodun Longe, FAS
University of Ibadan

GM technology and its applications are surrounded by a number of concerns. Some aspects and consequences of the production and use of GMOs are viewed as posing threats to public health and biodiversity. These perceived adverse impacts could influence acceptance despite the potentials they have in contributing to food production, food security, human health, and nutrition. The major areas of concern are food and feed safety, human and animal health, as well as environmental safety. There are concerns that food and feed made from or containing GMOs may give rise to allergenicity, toxicity, or result in horizontal gene transfer-particularly of antibiotic-resistant genes. There are also fears that the use of GMOs may impact on non-target organisms, that transfer of genetic material from one organism to another may occur, and there could be an overall negative effect on the ecosystem. However, scientific proof is needed to substantiate these claims.

The recommendations of NAS regarding the use and regulation of GMOs in Nigeria are as follows:

- Regulations should be enforced to minimize risks and maximize benefits. Claims of safety must be scientifically validated
- Every GMO should undergo thorough testing and mandatory review. Rigorous long term monitoring is also required

- The government should rely on scientific research for setting standards. Nutritional standards should be harmonized with Codex standards
- There should be strict guidelines to check and control the inflow of GMPs, even genetic materials for research purposes
- Nigeria's research capacities must be strengthened. Government should invest in local research and put in place relevant structures geared towards development of country-specific products
- The outcomes of research on GMOs should influence government policies that protect health and natural resources

Audience reflections

- *There are risks with every novel technology but that doesn't mean that we should not move forward. There are risks associated with biopharmaceuticals, but the benefits that can be gained from GMO use cannot be overlooked. Nigeria is ready for GMOs. Our needs have been taken into consideration. We must take our destinies into our own hands*
- *The implementation of GMOs will help address food security issues. We can improve the quantity and quality of the food produced and consumed. There are however challenges. Funding for research is key. The scientific community should try to engage with organizations that are anti-GMO to present the scientific evidence of 'why support GMOs'*
- *Life is about taking risks. GMO technology is an offshoot of biotechnology which has been around*

for a long time. There is a need to support the relevant agencies to carry out their activities. NABDA and African Agricultural Technology Foundation (ATTF) instituted the Open Forum on Agricultural Biotechnology in Africa (OFAB) to provide the public with evidence based information on GMOs. Stakeholders must play their part to create awareness by forming a network to dispel public mistrust and fears

- *Processes used for the certification of GMOs should be made open to stakeholders including the press. There should be transparency in every sphere involving GMOs*
- *GMOs are one of the most monitored materials; anywhere they are approved, monitoring and evaluation is continuous. Monitoring and evaluation most be instituted and made continuous in Nigeria*
- *The NBMA and NABDA should have a compilation of Nigerian GMO experts as they are scattered all over the country so they can be involved in cooperative research*
- *Running biotechnology laboratories in Africa including Nigeria is challenging. Issues with power supply and procurement are commonplace The government should make adequate funding for research available and such fund should be used prudently to fill these gaps where they exist*
- *NBMA and NABDA should go around the country to document ongoing research activities in biotechnology. We should create a network on this issue. We can't go back; these agencies must*

be supported to survive. We should also support individual researchers across the country. The NBMA must have its own laboratory facilities to assess the quality of GM products being brought into the country

- *Efforts are being made to introduce biotechnology into the curriculum at primary and secondary school level. This has been challenging; but the push for this is still ongoing.*
- *It is difficult to fault Nigeria on the content of her policy documents; our policies are usually excellent. Implementation is where we usually fall short. The biosafety regulatory frameworks are excellent. It took 14 years to develop; it can therefore not be faulted; an indication that Nigeria is ready to embrace GMOs*
- *No one intends for GM crops to replace conventional agriculture. They are meant to be complementary; for our comfort and convenience*
- *The concept of fortifying foods like cassava and sorghum were unimaginable in decades past. The fears of the effects of consuming GMOs are without scientific basis. Scientists therefore should not endorse such claims. Efforts should be made to promote GMOs and biotechnology in Nigeria. Though there are challenges, which can be overcome*
- *All the issues identified at this meeting should be put forward to the government. Civil Society Organizations (CSOs) that are against GMOs in Nigeria must be engaged so as to educate them on the science and economy gains behind the support of GMOs*

The Way Forward

Participants at the roundtable put forward the following suggestions and remarks regarding the way forward for GMO us in Nigeria:

1. The current scientific consensus regarding GMOs is that they are safe for use; they have been approved by the WHO, FAO, as well as academies of science across the globe. Based on the available evidence, the science of GM technology is deemed to be sound.
2. Presently, there is no scientific evidence that buttresses the claims regarding adverse effects of GMOs including their purported allergenicity, toxicity and lateral gene transfer.
3. Despite the lack of evidence regarding the adverse effects of GMOs, the Nigerian scientific community should carry along all relevant stakeholders including opponents of GMOs and biotechnology in building consensus.
4. Constant monitoring and evaluation is vital and the scientific community must be at the forefront of this. If concerns arise, scientists should call the attention of other relevant stakeholders to such.
5. The capacity of the NBMA and NABDA should be strengthened and continuously improved, (maintained) particularly with regards to funding.
6. Monitoring and evaluation is the major role of the NBMA and this should be continuously and effectively performed across the country.
7. Biotechnology research should not be domiciled in the NBMA and NABDA alone. It should feature in research institutions across the country as well as in private establishments. Consequently a data repository of all biotechnology research areas being carried out in Nigeria should be collated by the NBMA.

8. A conducive environment for research should be a top priority for Nigeria. Government funding for research in general and biotechnology in particularly is important for Nigeria's development. (Researchers, on their own part, should develop appropriate proposals and budgets for their research.

Appendix One: Roundtable Agenda

Opening Session

Welcome remarks
Professor Oyewale Tomori FAS- *President, NAS*
Professor Lucy Ogbadu – *Director General, NABDA*

Self-introduction by participants

Overview of roundtable objectives and expected outcomes
Dr. M. Oladoyin Odubanjo- *Executive Secretary, NAS*

Session One
GMOs IN NIGERIA- legislation, governance, and potential benefits
Moderator- Professor Oyewale Tomori FAS

Overview of GMOs
Dr. Mohammed Yerima- *Department of Microbiology and Biotechnology, Federal University, Dutse*

Unveiling molecular techniques in GMOs: the implication for public health and safe
Dr. Francisca Oby Nwaokorie- *Senior Lecturer Department of Medical Laboratory Science, College of Medicine, University of Lagos.*

GMOs in Nigeria
Dr. Rufus E. Ebegba- *Director-General/Chief Executive Officer, NBMA*

Discussion- The case for GMOs in Nigeria

Discussion points

- *Does Nigeria need GMOs and are we equipped for their use and regulation?*
- *What was the extent of stakeholder engagement in the development of the National biosafety law?*
- *What is the level of public awareness/education regarding GMOs in Nigeria?*

Developing Transgenic Crops: The Brazilian success Stories.

Dr. Abdulrazaq Ibrahim- Department of Biochemistry, Ahmadu Bello University, Zaria

Discussion

Session Two
POTENTIAL IMPACTS AND BENEFITS OF GMOS IN NIGERIA
Moderator- Professor Adeyinka Afolayan FAS

Potential impacts and benefits of GMOs –.health, environment, agriculture.

Professor Isaac Adeyemi, FAS - *Ladoke Akintola University of Technology*

Discussion

Discussion points:

- *What positive impacts can GMOs have on Nigeria's critical sectors?*
- *How can GMOs improve health in Nigeria?*
- *Is Nigeria ready / prepared to take advantage of GMOs?*
- *Human gene editing/ microbial genetic manipulation*

Session Three
PANEL DISCUSSION- Areas of concern
Moderator- Professor Olusegun Ekundayo FAS

Opening remarks - Areas of concern regarding GMOs

Professor Oyebiodun Longe, FAS
University of Ibadan

Panellists' remarks

Professor Tola Atinmo, FAS-*University of Ibadan*
Professor Lucy Ogbadu
Dr. Rose Gidado- *Assistant Director NABDA and Country Coordinator Open Forum on Agricultural Biotechnology (OFAB)*

Questions and answers/Discussion-resolving areas of concern

Discussion points

- *Are the perceived/potential drawbacks of GMOs valid or unscientific?*
- *What lessons can Nigeria learn for other countries – US, EU, India, and particularly Africa?*
- *What measures/strategies can be put in place to dispel the existing concerns?*
- *How can the persisting public mistrust of GMOs be addressed?*

Session Four
General Discussion
Moderator- Professor Efiom Ene-Obong FAS
Recommendations and the way forward

Closing remarks

Professor Efiom Ene-Obong FAS

Appendix Two: Participants List

SN	NAME	AFFILIATION
1.	Professor Oyewale Tomori FAS	NAS
2.	Professor Oyebiodun Longe FAS	NAS
3.	Professor Adeyinka Afolayan FAS	NAS
4.	Professor Olusegun Ekundayo FAS	NAS
5.	Professor Tola Atinmo FAS	NAS
6.	Professor Israel Adu FAS	NAS
7.	Professor Efiom Ene-Obong FAS	NAS
8.	Professor Isaac Adeyemi FAS	NAS
9.	Professor Sylvia Malomo	Nigerian Society of Biochemistry and Molecular Biology
10.	Dr. Mohammed Yerima	Department of Microbiology and Biotechnology, Federal University Dutse
11.	Professor Moji Bakare-Odunola	Science Association of Nigeria (SAN)
12.	Professor Valentine Aletor	The Federal University of Technology Akure (FUTA)
13.	Dr. Emmanuel Odjadjare	The Nigerian Young Academy (NYA)
14.	Professor Benjamin E. Ubi	Biotechnology Society of Nigeria
15.	Dr (Mrs.) Dike Ekaette Nduka	Federal Institute of Industrial Research FIIRO
16.	Dr. Bamidele Iwalokun	Nigerian Institute of Medical Research (NIMR)
17.	Ms. Omolola Ajakaiye	Consumer Protection Council
18.	Mrs. E. Abimbola Francis	Lagos State Chapter, All Farmers Association of Nigeria (AFAN)

19.	Mrs Kemisola Ajasa	Nestle Nigeria PLC
20.	Dr. Modupe Akinyinka	Department of Community Health and Primary Health Care, Lagos State University College of Medicine
21.	Dr. Modupe Akinyinka	Department of Community Health and Primary Health Care, Lagos State University College of Medicine
22.	Ms. Olubunmi Joyce Ajiboye	Flour Mills of Nigeria
23.	Professor Olubunmi Otubanjo	Department of Zoology, University of Lagos.
24.	Dr. Taiwo Idowu	Department of Zoology, University of Lagos
25.	Dr. Melaku Gedil	International Institute of Tropical Agriculture (IITA)
26.	Mr. Rufus E. Ebegba	NBMA
27.	Dr. Rose Suniso Maxwell Gidado	NABDA/ OFAB
28.	Dr. Abdulrazaq Ibrahim	Department of Biochemistry ABU, Zaria
29.	Professor Lucy Ogbadu	NABDA
30.	Dr. Francisca Oby Nwaokorie	Department of Medical Laboratory Science, College of Medicine University of Lagos.
31.	Mr. Yarama Ndirpaya	Agricultural Research Council of Nigeria
32.	Mr Umaru Joseph Abu	African Agricultural Technology Foundation (AATF)
33.	Sarah I. Omeje	OFAB
34.	Modesta Abugu	OFAB
35.	Dominica Omozusi	OFAB

36.	Dr. Kollo A. Issoufou	AATF
37.	Dr. Doyin Odubanjo	NAS
38.	Miss Bolaji Dasaolu	NAS
39.	Mrs. Ife Edawole	NAS
40.	Miss Anjola Olanipekun	NAS

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