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## Biotechnology as a Change Agent for National Development: Review in The Gambia

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### Abstract

Biotechnology is an important tool which can ensure the production of crop that will have longer shelf live, drought resistant, high saline tolerance, ability to withstand adverse conditions among others. The Gambia among the low-income West African countries, where agriculture is practiced by two-thirds of its citizens and couple with global population which is now around 7 billion predicted to rise to 9 billion by 2050, the Gambian government really needs to act fast and positively in welcoming genetically modified crops if it's to be able to feed its population now roughly around 2 million people. Application of Biotechnology in crop and animal farming through genetic engineering has led to the development of crops with desirable characteristics such as crop varieties that cope better with drought and salinity, crops that more resistant to pest and diseases and crops that use nutrients more efficiently. This can help transform The Gambia into a country with a robust agriculture capable of not feeding the nation but also generating substantial foreign exchange. Through Agricultural biotechnology, this looming crisis can be averted eradicating malnutrition by ensuring food self-sufficiency through the production of resistant crops to pests and diseases, having longer shelf-lives, higher nutritional content and palatability, higher yields and early maturity period, tolerant to adverse weather and soil conditions. Achieving food sufficiency which is a direct consequence of a flourishing agricultural sector will facilitate a shift from other natural resources as a source of foreign exchange thus promoting economic diversity through agriculture.

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## 1. Introduction

Africa is continent blessed with a affluence of natural resources. Though unevenly distributed, these resources have the potential to drive economic growth and social development. These resourced include land, minerals, biological diversity, wildlife, forests, fisheries and water. Africa's economies and people are also vulnerable to environmental hazards such as droughts and floods, and climate change adds to the frequency and extremity of these natural events. In addition, sub-Saharan Africa is experiencing faster degradation of many environmental resources which in turn has direct and indirect effect on agriculture. This, more highly affect more poor people than in any other region of the world [6]. One of the greatest challenges facing agriculture in African today is to improve the nutrient status of agricultural lands, many of which are acidic, low in phosphorous and high in toxic aluminum. Some soils samples are naturally richer in nutrients than others and can be exploited for a while eventually leading to nutrients loss which have to be replenished. Without nutrient replacement, there is no agricultural sustainability [34]. In 2003, the United Nations Industrial Development Organization (UNIDO) summoned a meeting in Nairobi to address the question of which biotechnological interventions were most important to Africa. Agricultural experts from around the continent were tasked to find solutions to problems of agriculture in Africa by focusing on two objectives. Firstly, what interventions are readily available for adaptation to Africa, and secondly, what are the most pressing problems even if the solutions lay some years in the future. Based on these, they came up with a list of possible solutions which include [34].

- i. insect-resistant African maize varieties expressing one of the *Bacillus thuringiensis* (Bt) cry genes coding for insect-specific toxins;
- ii. crops resistant to African viruses such as the maize streak virus (MSV) and the African cassava mosaic virus (ACMV);
- iii. maize resistant to the parasitic weed, Striga
- iv. decreased levels of mycotoxins in maize, which may be possible due to diminished post-harvest fungal infection in Bt maize varieties; and Drought-tolerant crops [34].

However, with these resolutions in mind, scientists began to embark on several breakthrough researches with the intention of alleviating the problems being faced. These research so far suggests that genetic engineering can be used to develop crop varieties that cope better with drought and salinity [42-35] are more disease resistant [29-11]; and use nutrients more efficiently. These features are particularly desirable in a changing climate like Africa where the population grows and competition over arable land increases. However, agricultural biotechnology is a controversial topic, and not everyone is convinced that the net benefits of genetically-modified (GM) varieties will be positive overall [18]. Genetic engineering (GE) techniques are employed in few countries in Africa with the commercialization in South Africa, Egypt and Burkina Faso in crops with desirable traits such as insect-resistant cotton and maize, as well as herbicide-resistant soybean and/ or the combination of these traits. Agricultural biotechnology research in Africa also focuses on controlling diseases and pests; improving the storage properties of crops and food; improving weed control, improving yield and quality of foods; protecting natural resources; drought and salt tolerance and biofuel production. Bio scientific

researchable areas include insect resistance, virus and bacterial resistance, drought tolerance and fungal resistance. Aside from pest and diseases protection, attempts are being made on nutritional quality improvements, such as bio-fortification of sorghum, cassava, etc. with vitamins and proteins [9]. This review looks at the role modern biotechnology can play in addressing the various problems of agriculture in The Gambia and critically looks at how this translates into a tool that can be used to drive development and agricultural sustainability in the small West African Country that rely almost entirely on agriculture for sustenance and development.

## **2. Why The Gambia need GM crops**

The Green Revolution in agriculture passed hardly unnoticed in Africa. While in Asia and Latin America the introduction of improved crop varieties and the application of scientific farming methods enabled enormous food production which outstrip population growth, in Africa agricultural productivity actually declined [14]. West African countries have become ever more dependent on imported rice from Asia over the past decades. Inexpensive Asian rice and declining tariff barriers facilitated West Africa's increase in rice imports. Several Southeast Asian nations became major rice exporters in the 1970s following the first Green Revolution and significant investments in irrigation infrastructure [25]. The Gambia is among the low-income West African country, where agriculture is practiced by two-thirds of its citizens. Groundnut are the primary export crop, with rice, millet, and sorghum traditionally planted for food [25]. Over the second half of the 20th century, The Gambia became increasingly dependent on rice as the nation's dietary staple, but the country's farmers proved unable to improve their market share of the increased urban demand for rice. Their capacity was undermined by the implementation of economic reforms in the mid-1980s, which eradicated producer subsidies in favor of market-based solutions and inexpensive imports. As a result, domestic rice production stagnated and milled imports climbed [25]. Global population is now around 7 billion and it is predicted to rise to 9 billion by 2050. The recent Foresight report suggested that demand for food could rise by 70% by 2050 [39], with most of this demand is likely to come from developing countries like The Gambia. Research has shown that, optimal places to improve crop yields are areas such as sub-Saharan Africa, where 96% of farms are rain-fed [13], with low inputs in terms of soil improvements or fertilizer [9]. The Gambia government really needs to act fast and positively in welcoming genetically modified crops if it's to be able to feed its population of roughly 2 million people. Rice is seen as national symbol of cultural identity in The Gambia. Every house hold in the Gambia feeds on it almost every day. Yet, the country's rice farmers, who remain principally women, are unable to take advantage of the growing urban demand for the grain. This is not actually because their rice is costly to grow but because the transportation, marketing infrastructure, and farm subsidies available in many rice-exporting countries do not exist in the Gambia. In dismantling the capacity of the state to provide agricultural services, the economic reforms contributed to disenfranchising domestic rice growers from a ready market for their output [25]. Biotechnology is the only tool which should ensure the production of early maturing crop, longer shelf live, drought resistant, high saline tolerance crops among others. Bio-fortification is the process by which the nutrient levels of food crops are increased during plant growth through agronomic practices, conventional plant breeding, or modern biotechnology [43]. This practice can be accepted and implemented widely in the Gambia on almost all crops varieties grown in the country and it would in no time address the issue of micronutrient malnutrition in the country [14]. The Government should encourage and enhance the effort of united purpose

(formerly known as concern universal). According to the project manager of united purpose they have secured a grant from the European Union to Bio-fortify pearl millet (“suno”). This crop is one of the staple food in the Gambia and it will no doubt contribute in the fight as malnutrition in the Gambia [33]. Herbicide tolerant crops are engineered to survive the application of most herbicide that would kill a non-engineered crop, making them easier for farmers to use more herbicide to control nearby weeds. Insect-resistant crops are engineered with an insecticidal protein from a soil bacterium, *Bacillus thuringiensis* (Bt). Bollworm insect is well known for its effect on cotton crop worldwide. Bt cotton has the ability to resist cotton bollworm insect, and this can save Gambian farmers all the trouble caused by this insect and it would in no doubt enable the cotton industry to regain its lost of high and qualitative exportation of this product. Improved crop varieties have also been developed to thrive in regions with very little rainfall (Drought resistance GM crops) and high salinity. A typical example which the Gambian government can adopt is the Nitrogen-use, water-use and salt tolerant rice species especially in rice fields around the Lower and Central river regions respectively in the Gambia. There are so many other crops under development, which the Government can invest in, such crops includes soybeans with higher protein content; potatoes with more nutritionally available starch and with improved amino acid content; pulses such as beans which have been altered to produce essential amino acids; crops which produce beta-carotene; and crops with a modified fatty acid profile [27]. Different types of peppers and melons with improved flavour are currently under field trials. This Flavor can also be improved by enhancing the activity of plant enzymes which transform aroma precursors into flavoring compounds [37].

### **3. Animal biotechnology**

Animal Biotechnology has been practiced in one form or another since the beginning of the domestication of animals [10]. Many of the previously used tools of animal breeding, genetics, and nutrition have played and will continue to play an important role in the selection, and management of desirable and economically important characteristics in livestock. However this technology is slow with generation of undesired results due to the uncertainty of the manipulations. In the future, livestock production will rely even more heavily on this emerging biotechnological advances to produce our food. Yet, improvements are still needed in product composition and production efficiency, especially in growth, disease resistance, and reproduction [10]. Biotechnology can be employed in the Gambia to improve and breed ruminants in enormous numbers and cheaper for the general public especially when it is “Tobaski” period there by making ram and ruminants readily available and saving the government the trouble of importing livestock. Animal products such as milk, meat, hide and skin and bones quality and quantity can be improved through biotechnology. This will help produced breeds for special purposes. For instance special dairy cattle are for milk purposes. Animals with special meat quality can also be produced through biotechnology [10].

### **4. Genetically modified (transgenic) livestock**

Stem cells, and other emerging biotechnologies will have important roles in producing more and higher quality food derived from livestock. The advancement of biotechnology has led to a distinct shift in the economic returns from livestock. Livestock production has currently accounted for about 43% of the gross value of agricultural production. There has been a constant increase in the demand for livestock and livestock related

products worldwide [10] With genetic manipulation and related technologies gaining prominence more and more, research interests to improve livestock using genetic engineering has become a buzzword today [11]. Globally, livestock production is reported to be the fastest growing sector than any other sector, and by 2020 livestock production is predicted to become the most important agricultural sector in terms of added value.

## **5. Gmo's To Solve Food Security**

Gambian Irrigated Rice Development was between 1966 and 1984 and the international development assistance sponsored pump-irrigation rice projects on the Gambia River's plentiful alluvial swamps especially around the Lower and Central river regions of the country. The objective was to modernize production of a prominent dietary staple with the introduction of Green Revolution Asian rice varieties. The projects aim was to shift rice from seasonal to year-round cultivation, thereby enabling two annual harvests instead of one. One harvest was to secure household subsistence requirements, whereas the second offered a cash crop to raise farm incomes. Double-cropping would strengthen rural food reserves and generate surpluses to meet urban demand [25]. Despite this project and many that follows after it, the Gambia still continues to import Asian and American grown rice. The Gambia government has the ambition of reviving the nation's economy and to also make it a food sufficient within the next five years this could be possible because the country has the land and a navigable river, with fresh water flowing in most part of the river Gambia across the country [33]. Food security is not just about excessive production or supply of food but access to it counts greatly, but in sub-Saharan Africa, increasing productivity has a particularly important role because the majority of the hungry individuals are in fact farmers and farming communities [31]. The Gambia also faces a looming food security crisis with a growing population that is increasingly dependent on imported foods coupled with the fact that most food commodities in the country are expensive for an average civil servant in the Gambia to purchase. According to Food Agriculture Organization (1996) food security is a situation when all people at all-time have physical and economic access to enough, safe and nutritious food for a healthy and active life [22]. Food security involves the stage at which every Gambian can boast of having three safe and nutritious meals a day. This as we know is a tradition in the Gambia, most families can barely afford three square meals a day even though the quality and quantity may be questionable. As matter of fact we are right to say that, the Gambia is as a nation is faced with high food insecurity crises. Food insecurity on the other hand boils down to inability of households to have reliable access to food in sufficient quantity and quality to enjoy active and healthy life [12], Agricultural biotechnology has the solutions in eradicating malnutrition, hunger and provide food self-sufficiency through the production of resistant crops to pests and diseases, having longer shelf-lives, higher nutritional and palatability, higher yields and maturity period, tolerant to adverse weather and soil conditions, generate employment and as well economically empower farmers among other benefits [38]. Gambian government needs to invest heavily in the cultivation and usage of Genetically Modified Crops (GMC) in order to be able to overcome the issue of food insecurity, malnutrition, starvation and fight hunger in the country. Even though, critics of the use of GMC's argued that, its usage has dangerous effects on the health of the human populace and the ecosystem at large even though there is no evidence to back their claim, notwithstanding these are sufficient reasons why much research needs to be carried out to properly address and prevent any possible risks that may be associated with the consumption of GMCs [27].

## **6. Climatic changes and biotechnology**

Since the mid eighteenth century, the average temperature of earth has increased by 5.4% with 4% of this increase in the past 25 years alone. This significant rise in surface air temperature has initiated a cascade of present and future changes, including a rise in sea level, predicted to rise by 59 cm in the 21st century [8]. This is a menace to coastal communities, corals and wet lands around the world, along with rapid temperature increase globally since 1990. The over-all impact of climate change as it affects agriculture includes; Increases in average temperature, Change in amount of rainfall and patterns, rising atmospheric concentrations of CO<sub>2</sub>, Pollution levels of tropospheric ozone (or bad ozone that can damage living tissue and break down certain materials), Changes in the frequency and severity of heat waves, drought, floods and hurricanes and Climatic changes will obvious affect agricultural systems [41]. Agriculture is a source of livelihoods for about 86 percent of rural people (2.5 billion people) and provides jobs for 1.3 billion smallholders and landless workers. A more dynamic and inclusive agricultural sector could dramatically reduce rural poverty, helping countries meet the Millennium Development Goals of halving poverty and hunger by 2015 [43], which will likely be the most severely affected. To mitigate the effect of climate change, current agricultural approaches need to be modified and innovative adaption strategies need to be in place for the efficient production of more food under unfavorable conditions and with the reduction in greenhouse gas emissions [14]. The Gambia's climate is Sahelian characterized by high variability in the amount and distribution of annual precipitation [23]. Analysis of long-term climate data shows that the past 50 years have seen a decrease in total amount of precipitation, length of rainy season, and increase in length and frequency of extreme weather events such as droughts and dust storms [27]. The low-lying topography, combined by high dependence on subsistence rain-fed agriculture and inadequate drainage and storm water management system in a context of rapidly expanding unregulated urban expansion has placed the Gambia among those countries most vulnerable to climate change. The Gambia has experienced various adverse impacts of climatic change, climate variability, and extreme weather events [23]. Agricultural biotechnology will play a role as one of the several tool available in fighting against climatic change. Biotechnology and specifically genetically modified (GM) crops can, and is already making important contribution by reducing the emission of carbon (iv) oxide and mitigating the impact on food security and also improve nutritional value [24]. Genetically modified crop thrives in extremely high temperature, such as the Africa Bio-fortified Sorghum (ABS) by introducing trait to make the crop drought tolerant. However a multidisciplinary approached has been suggested that includes both biotechnology and traditional method.

## **7. Biotechnology and Economic Diversification**

Every country has one natural resource or the other and sources of generating national revenues but always sorts for more ways of concretizing, improving and sustaining its economy. Economic diversification should be the quest of every country in order to avoid some unforeseen circumstances at the detriment of their citizens. Scientific advances through the years have relied on the development of new tools to improve socio-economy such as health care, agricultural production, and environmental protection [27]. A lot of arguments are circulating in the world especially in Africa concerning the practice of Biotechnology particularly in the food sector. At present, out of the 54 recognized countries in the African continent, only 4 countries, namely; South Africa, Egypt, Burkina Faso and Sudan has accepted this promising technology. Individuals, consumers,

policymakers, and scientists must therefore ultimately decide if the benefits of biotechnology are greater than the risks associated with this new approach [37]. The Gambia is a small country with a population of 1.4 million in 200 with about 40% of the people live in the urban areas. The population growth rate is at 1.9% per annum a population density of 128 persons per square km. 49% of the people live in the rural areas and about 60% of the population is under 25 years of age. The Gambia has a narrow economic base, relying heavily on its agriculture and related natural resources to provide livelihoods for over 60 percent of the Gambian peoples. Since 1994, the Gambia has been defining and implementing Poverty Alleviation and Reduction strategies aimed at operationalizing the Country's Vision 2020, and more particularly addressing the human dimension of continued economic growth and Millennium Development Goals of the country [16]. The Gambian economy has a narrow base with a large re-export trade comprising about 80 percent of the country's merchandise exports, and contributing about 53-60% of domestic tax. Its total trade was 106% of GDP in 2006 and presently stands at 74% of GDP. The sectors dominating The Gambian economy are: services, 59 %, Agriculture 28-30 %, Tourism 12 %, Manufacturing and Construction 12 % of the country's GDP. Real GDP growth at factor cost was 7.2% in 2008, Domestic Debt was 32.2 % of GDP in 2008 (The Gambian Agriculture and Natural Resources [32]. Poverty levels in the Gambia as at 2003 was 61%. Poverty has been identified as a rural phenomenon but recent information indicates that it is an increasing urban phenomenon. About 91 percent of the ultra-poor and 72 percent of the poor live off agriculture as their main source of livelihood [32]. This is quite high and the Gambian government must devise means by which its economy can be boosted. There is no other way than investing in biotechnology. Key critical constraint in biotechnology acceptance and practice have been identify in the Gambia. These include: inadequate human and infrastructural capacities, very low awareness by public and private sectors on the importance of biotechnology to enhance cost effective achievement of food, agriculture and nutrition objectives, negligible institutional framework for research, extension and investment in biotechnology [32]. Nevertheless, this should not be an impediment to the potentials biotechnology has in changing the dance tune of the Gambian economy. Looking at the Gambian economy, biotechnology can provide solutions to a number of crime related puzzles, breakthroughs in the health sector, upgrade for the agricultural sector and consequently add to the financial purse of the country, adding that the sector was still untapped in the country despite its enormous benefits. Biotechnology can overcome the challenge of food shortage because it is able to produce plant varieties that provide reliable high yield, resistance to diseases, pest and stress factors which will contribute gainfully to food production while maintaining a healthy environment by reducing the amount of fertilizer, pesticides, and herbicides used in farming. This is all achieved at low cost than the normal traditional way of farming. These benefit will open opportunities for capacity building, numerous jobs creation, and reduce poverty as well as ending malnutrition. This technology does not only stand to provide sufficient food to the Gambian citizens but also for commercialization which will greatly boost its economy. Biotechnology has made India which was least known in agriculture became world's largest producer of cotton; Argentina leads in the production and export of soybeans and Burkina Faso, in the last two years became Africa's largest producer of BT cotton. This therefore becomes of utmost importance that Biotechnology must be employed rather than relying on the usual way of peasant farming which is challenged with serious problems such as climate change, erosion and leaching of farm lands, arid and unfertile lands. The health of every individual is a key to his survival. In the health sector, biotechnology can provide reliable and better diagnostic, management and prevention of disease. Diseases that are of genetically origin can be predicted

for several generations to come which will help save millions of individuals that are at risk of suffering from such disease. If the citizens are healthy, the productivity of the country will surely be high. Most of the diagnostic procedures now employ the use of kits. These kits are developed from biotechnological research. If the Gambian government will establish biotechnology based research laboratory that can produce their own kits, it will save the country from importation of health facility but rather exporting, as with any commitment of resources, investments in biotechnology should be weighed up against other potential uses of these resources in developing countries [29]. Biotechnology is a broad range of technologies that use living organisms or parts of them to make diverse products. For example, medicines and therapeutics, nutritional compounds, environmentally friendly chemicals and materials, biofuels, and novel functional materials can be produced through biotechnology. Biotechnology is also used to degrade toxic or harmful chemicals and agents to solve environmental and industrial problems. Biotechnology has been used to tackle large national issues such as healthcare. Deloitte have forecast the world's major regions health care spending to increase from 2.4 percent to 7.5 percent between 2015 and 2020 [7]. With Biotechnology, even as the population grows, costs should not increase thanks to technologies such as efficient disease prevention and wellbeing programmes, precision medicine, genome editing, organ production, and stem-cell therapy. The biotechnology industries in the developed countries tend to focus on solutions for chronic diseases that are predominant in their population namely, cardiovascular disease, diabetes, and tobacco-related conditions [38]. They have shied away from research in tropical disease due to poor market return and intense competition, therefore the biotech industry in developing nations has started developing more effective treatments to address their own health concerns and food science issues. For example, sub-Saharan Africa has only about 10 percent of the world's population but is home to more than 60 percent of the world's HIV-infected population and nearly 10.3 million people are receiving antiretroviral therapy in eastern and southern Africa [39]. As a result, most research efforts centre on the development of a vaccine for HIV. South Africa has been conducting clinical trials for HIV-candidate vaccines. This effort has been coordinated formally since 1999 by a joint government and private-sector initiative known as the South African AIDS Vaccine Initiative [30]. Another African country that has rose up to the challenge is Egypt, they were facing a shortage of insulin and an overdependence on the importation of insulin from overseas. A rapid development program sponsored by the government has allowed 90 percent of Egypt's insulin to be produced domestically and has saved millions of dollars for the national health system [21]. Egyptian scientist are currently working on getting a cure for diabetes using stem cells). Kenyan farmers are benefiting from the nation's growing biotechnology sector, which has produced disease-free cotton and banana plants, made by laboratory tissue cultures that offer greater yields. The plants were produced in local laboratories funded by joint public and private ventures [20].

## **8. Health and Education**

A strong healthcare and educational system is also critical to development of a biotech industry. In Cuba, Fidel Castro's revolution ushered in an emphasis on science, education, and health [36]. Cuba's health system and its research sector are intertwined; almost every health centre is part of a national clinical trial program. While Cuban hospitals generally suffer from a lack of money, supplies, and drugs, its citizens nonetheless enjoy a high standard of health in comparison to many developing nations, with the island boasting an average life expectancy of 76.7 years [40]. In the 1980s the Cuban government spun a meningitis B epidemic (more than



200 childhood deaths yearly) into a successful vaccine that, with its highly cost-effective hepatitis B vaccine, is exported by the World Health Organization to developing nations worldwide [4]. Cuba not only export vaccine but also export doctors and Gambia has been benefiting from Cuban Doctors for more than a decade.

## **9. Recombinant vaccines**

Vaccines are arguably the most important medical advance of the last hundred years. Vaccination has resulted in the eradication of smallpox, the imminent eradication of polio, and a dramatic reduction in the prevalence of many other infectious diseases [1]. Advances in vaccine research are expected to impact not only communicable diseases, but also non-communicable ones such as cancer. Recombinant technology makes it possible to have single proteins of a pathogen produced in non-pathogenic microorganisms. This obviates the risks associated with conventional live, attenuated vaccines while conferring immunity against disease. Recombinant vaccines may also prove to be cheaper because of innovative production methods and, potentially, because of improved storage characteristics (such as longevity and resistance to breakdown). Much progress is being made in recombinant vaccine development but there continue to be challenges such as, for example, correct presentation of recombinant antigens to the immune system and lengthening the lifetime of the engineered protein in the body. A variety of recombinant vaccines exist, the most promising being viral vector vaccines, naked DNA vaccines, and plant-derived vaccines. The subunit vaccine RTS,S/AS02 demonstrated to provide protection against natural malaria infection in adults in a clinical trial in The Gambia [3]. For the first nine weeks of the study, 71% of the participants were protected from infection. These are examples of how biotechnology has been used to affect national development in terms of health. Gambia has been blessed with one of the best research centres in Africa; Medical Research Centre (MRC the Gambia). The Gambia government in collaboration with MRC can use biotechnology to manufacture vaccines and other medical and lab equipment to make Gambia a leading market for healthcare. Thanks to MRC a lot of young Gambians are exposed to research so we now have the personnel and structures with MRC Farafenni being donated to the University of The Gambia. The government can follow the steps of China and Cuba in combining health care and education and within years The Gambia can be the place for health tourism in the region which will boost the economy of the country.

## **10. Biofuel Production**

Biofuel production is the trending technology worldwide as earth encounters pollution due to burning of petroleum, its products and coal based fuels. Petroleum fuels are finite reserves and most of its reserves are located in politically unstable countries. Alternative fuels are important for both environmental and energy security point of view. Along this line, many countries are formulating energy policies for the generation of renewable energy source. However at present, biofuels such as biodiesel and bioethanol are the renewable energy source which largely produced from edible food materials [28]. Various edible plant oils from soybean, rapeseed and canola oils are used for the preparation of biodiesel. Whereas, ethanol can be produced from a variety of feed stocks such as sugar cane, bagasse, sugar beet, grain, switch grass, barley, potatoes, molasses, corn, Stover, wheat and many other sources rich in carbohydrate [28-19]. Alternatively, nonedible feed stocks can be used for the production of biofuels. *Jatropha*, *Pongamia* and other nonedible plant oils are already used

for the preparation of biodiesel [19]. The Gambia government can encourage farmers to venture into the production of the above mentioned crops, and by so doing the nation can serve enough foreign exchange use in buying heavy fuel. Along this line, nonedible lingo-cellulosic biomass can also use for the production of bioethanol. Currently, technologies are available for the production of biodiesel and bioethanol in industrial scale. In this regard, a pilot scale production of ethanol from food waste using *Saccharomyces cerevisiae* H058 is already reported [44]. Nevertheless, low cost, greener and advanced technologies are needed for the production of fuels from food wastes [22-2]. The industrial production of biofuel from food waste is largely depended on: Availability of food waste, efficiency of hydrolysis process, the amount of lipid and carbohydrate obtained from food waste, and efficiency of fermentation and Trans esterification methods.

## 11. Biotechnology and conservation in the Gambia

The Gambia is endowed with a high biodiversity of plants and animals species (NBSAP of The Gambia, 2015). With the Banjul Declaration in 1977, Gambia shown its commitment to conservation. But an increasing human population, coupled with agricultural production practices which do not take in to account conservation, have led to the loss of a large proportion of The Gambia's forest cover together with many of the wildlife species ([www.gambia.dk/nature/intro.html](http://www.gambia.dk/nature/intro.html)). Currently, the biodiversity conservation strategy in the Gambia is almost base on the creation of protected areas. Biotechnological tools can help the Gambia in its biodiversity drive [3]. At present, The Gambia has lost over 13 species of mammals and unknown number of floral species. With only 22 wildlife protected areas occupying about 6.4% of The Gambia's total surface area (NBSAP of The Gambia, 2015), it means a lot of wildlife outside the protected areas are in danger of extinction. Therefore The Gambia need a gene bank. The Ministry of Forestry and NARI can collaborate to make this possible. There are of organizations involved in such programs. The International Plant Genetic Resources Institute (IPGRI) as well as the Consultative Group on International Research (CGIAR) centers are heavily involved in the conservation of rare and endangered plants species by maintaining in-vitro gene bank [30]. Tissue culture and micro-propagation are useful biotechnological tools that the Gambia can used in biodiversity conservation. Tissue culture is a useful technique to preserve somatic embryos which can be applied in the medium and long term conservation process [28]. While micro-propagation technique assists in the rapid, season independent, continuous propagation, storage and maintenance of rare and endangered plants by using plant parts as explant source [31]. Cryopreservation is the technique currently available to ensure the safe and cost efficient long-term conservation of species [31]. Such a technique can play a useful role in marine biodiversity conservation in The Gambia. Since there are limited information available on marine species diversity in the Gambia (NBSAP of The Gambia, 2015), biotechnological tools and techniques can help in obtaining more information about marine diversity and its conservation. Although, biotechnological methods can help The Gambia in biodiversity conservation but still it need to be combine with other technique like protected area method for maximum benefit.

## 12. Conclusion

Although it is a little bit certain that there could be some form of risk and skepticism associated with the use of this technology, it is however an utmost reality and fact we have to strive to depend on our own efforts and be

an exporting nation rather been a depending nation. This technology would in no doubt revive our falling Agricultural sector and regain its cotton export potential, produce high yielding crops among other benefits in the Country and enable us to regain our exporting ability and as well become food self-sufficiency as discussed in [14, 25, 25, 33, 37-43]. According to [3, 8, 14, 27, 30-43], this technology has the ability to mitigate and solve the climate change and environmental menaces in a Nation. As the Gambia and the world at large strive harder to combat environmental menaces, the adoption and use of this technology is in no doubt timely and necessary. As seen in [10] the use of biotechnology can drastically improve and increase the breeding of ruminants and this would solve the issue of insufficiency of ram during 'Tobaski' and other social or religious occasion in The Gambia. Moreover, adopting this technology as discussed in [16, 19, 22-27] would in no doubt help to diversify the Gambia and helps to make the nation a super power in the sub-region. Gambians have for long time being using genetically modified pharmaceutical products but are skeptical about GM crops. This is probably because, health challenges are placed as a priority over food production and consumption. However, what we eat is what we are. Many governments in the sub region are looking at the possibility of adopting GMO, we need to act fast, in fast tracking, adopting and commercializing GM crops and products. The faster we accept this fact and put policies on ground that will facilitate GM crop production, consumption and commercialization the better for us as a nation.

#### **12.1 Therefore the following recommendation would be made**

- The government in it capacity needs to put in place institution that would be mandated for the monitoring, implementation and adoption of this technology.
- The government of The Gambia and National Agricultural institution should be capable to successfully handle, develop and transfer some relevant knowledge in dealing with GMO.

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