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# AGRICULTURAL BIOTECHNOLOGY: A BRIGHT TORCH LIGHTING THE FUTURE OF INDUSTRIES

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# Agricultural Biotechnology: A bright torch lighting the future of industries

In a world that every day becomes more creative and more efficient at finding solutions for the sundry challenges that we face on Planet Earth, so much advancement continues to be realized. We continue the ancient wisdom of adapting and modifying living organisms through cellular and biomolecular process to facilitate human survival, well—being and progress—what is known as biotechnology (www.thebalance.com).

Several definitions of biotechnology have been suggested: Wieczorek (2003) defined it as the application of scientific techniques to modify and improve plants, animals, and microorganisms to enhance their value while Gupta (2001) described it as a range of scientific and engineering techniques for applying biological systems to the manufacture or transformation of materials in order to develop novel processes and products. Biotechnology today is a very complex scientific discipline that is galaxies away from its ancient ancestor where simple processes like fermentation of fruits was used to make alcohol and souring of fresh milk to make cheese. In this age, biotechnology features more complex techniques like cell and tissue culture, genetic engineering, genome sequencing and genome editing. It is used in sectors such as agriculture, medicine, industry and criminal investigation, among others. But this brief will narrow down to biotechnology as it is applied in agriculture today.

According to the Ministry of Agriculture, Animal Industry and Fisheries (2013), agriculture refers to the growing of crops, livestock or fish. Increased agricultural productivity is needed in Uganda due to a rapid population growth of 3.0% per annum (UBOS, 2016). The products of agriculture are used as a source of raw materials in many agro-based industries. In Uganda, the industrial sector is dependent on the agricultural sector (Rosenstein-Rodan 1943, Schultz 1953, Lewis 1954). Agricultural production can be increased through biotechnology by increasing crop productivity, enhancing crop protection, better flavor and improving food processing and nutritional value in food (Wieczorek, 2003).

Agricultural biotechnology is the use of scientific tools and techniques to modify living organisms e.g. plants, animals and microorganisms, in order to yield improved or altogether new agricultural products. It includes genetic engineering, molecular markers, molecular diagnostics, vaccine development and tissue culture, among others. Contemporary examples in crop farming and animal husbandry include genetic engineering for introduction of desirable genes such as insect resistance; gene silencing for inactivation of a specific gene used for disease resistance breeding for example the cassava with resistance to cassava brown streak disease; somatic cell regeneration for cloning of plants and animals to produce identical populations with shared preferred qualities; protoplast fusion involving the joining of cells or cell components to transfer traits between crop species for example the pomato that produces potatoes and tomatoes; polyploidy used to modify the number of chromosomes in a crop in order to influence its size or fertility; among others (UBIC poster).

Agricultural biotechnology can be used in many ways; genetic engineering where scientists have learned how to move genes from one organism to another across species barriers molecular markers used to select an organism with desired genes, molecular diagnostics used to detect the gene or gene product, vaccines used in animals and humans tissue culture which allows the reproduction of disease free planting material. Examples of crops produced using this technique are bananas, coffee, cassava, et cetera. Many agricultural biotechnology applications are an extension of traditional plant and animal breeding techniques, and they are often complementing traditional methods rather than replacing them. It focuses on improving the quality and standard of agriculture, increasing yield stability, and ensuring sustainable productivity.

Industrial sector development is undoubtedly a key priority for the Ugandan government and occupies an integral part of its social and economic development plan, "vision 2040". The industrial sector accounted for 21% of Uganda's GDP and employed about 7% of the labour force in 2017. However, the sector in Uganda is still very limited. In this essay the potential of agricultural biotechnology in boosting the industrial sector is discussed.

## 1) Food processing industries

The first food product resulting from genetic engineering technology to receive regulatory approval, in 1990, was chymosin, an enzyme produced by genetically engineered bacteria. It replaced calf rennet in cheese-making and is now used in 60 percent of all cheese manufactured. Its benefits include increased purity, a reliable supply, a 50 percent cost reduction, and high cheese yield efficiency (Wieczorek, 2003).

Genetic engineering has allowed new options for improving the nutritional value, flavor, and texture of foods. Transgenic crops in development include soybeans with higher protein content, potatoes with more nutritionally available starch and an improved amino acid content, beans with more essential amino acids, and rice with the ability produce beta-carotene, a precursor of vitamin A, to help prevent blindness in people who have nutritionally inadequate diets (Wieczorek, 2003).



First and foremost, agricultural biotechnology can be used to increase the amount of raw materials available to agro-processing industries. In developed countries, where it has been properly advanced and applied, one of the most applauded and widespread results of agricultural biotechnology has been an increase in the amount of agricultural products yielded, be it in crops (ISAAA, 2017), fish and animal husbandry. This too can be realized in developing countries like Uganda where the greater chunk of industries are agro-based relying on agricultural output. With more raw materials available, industries will be more productive, which in turn will mean increased income generated.

Talking of the merits of agricultural biotechnology in relation to agro-processing industries, the story doesn't end with just quantity produced, but goes as far as improving the shelf-life/ longevity of the raw-materials. Agricultural biotechnology can be used to improve the shelf-life of produce in storage and during transportation, primarily through improving the postharvest physiology of fruits and vegetables. For example grape production in Israel where grape varieties with longer shelf-lives have been developed (Lichter et al. 2016). Examples have also been seen in animal industry such as dairy farming, where in places like Netherlands, the physiology of milk has been altered to make it more long-lasting (JCR, 2007). This is especially beneficial to industries that have to fetch their agricultural raw materials from a long way off, because it enables them to stay fresh all the way to the industry rather than ripening or going bad on the way. In turn it means less raw materials are wasted, meaning more productivity of industries.

Furthermore, agricultural biotechnology can be used to produce nutrient-boosted products in the food-processing industry.

The improvement of the nutrition content of crops and animals is a major part of agricultural biotechnology today. Scientists across the world are using biotechnology techniques to create foods imbued with special desired nutrients such as foods with boosted content of vitamin A. For example there is our own Ugandan Banana 21 project which improved the nutrition value in bananas. There is also the Golden Rice project which is meant to produce rice that is rich in vitamin A so as to help reduce the incidence of blindness (FAO, 2015).

Agricultural biotechnology is necessary for improving the supply of raw materials for agro-based industries, like; flour mills, rice shellers, bread products, sugar factories, wineries, textile, etc. These industries spend a lot of money in order to maintain the supply of the raw materials from the agricultural sector. According to Ocitti, the managing director of Uganda breweries limited in 2016, the company invests Shs. 20 billion in agriculture to enable it collect over 25,000 metric tonnes of raw material from 17000 farmers from different parts of the country. This can be solved using agricultural biotechnology through plant breeding to raise and stabilize yields, and allowing farmers to have two harvesting seasons in the sane year e.g. for maize, sorghum hence increasing their productivity. For wineries and beverage industries, delayed fruit ripening increases the shelf life of the fruits. So, genetically engineered fruits are left to mature on the plant longer, and with longer shelf-life for shipping. Losses due to rotting of the fruits is prevented.

Similarly, improvement in the productivity of cash crops for example coffee, tea, through agricultural biotechnology can increase foreign exchange which can also boost the industrial sector through investment. The increased income associated with productivity improvement mostly will be spent on industrial goods hence boosting the industrial sector.



## 2) Textile industry

Agricultural biotechnology is used to improve natural fibres, create novel fibres and polymers, bio-fabrics, dyes and intermediates from micro-organisms, treatment of wastes of textile manufacturers and processors

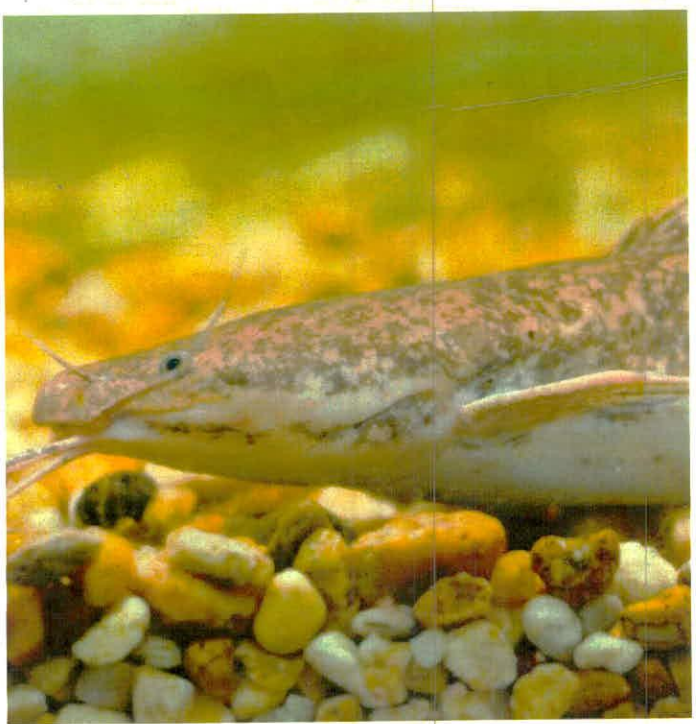
Cotton continues to dominate the market of natural fibers. Biotechnology has solved the major problems associated with cotton crop namely: improved resistance to insects, diseases and herbicides leading to improved quality and yield. Biotechnology has modified the properties of cotton such as improved strength, length, appearance, maturity and colour (Gupta, 2001).

Wool fibres are being improved in quality and yield by biotechnology techniques like use of DNA markers to identify useful genes. This helps breeders to accurately select rams for improved production and wool quality. The other technique is the use of genetic engineering to modify the genetic make-up of animals which produce wool, this includes the use of artificial insemination, semen freezing, embryo micromanipulation to produce animals with new genes for example a merino sheep which grows about 13% faster and larger than a normal one. In 1998, a revolutionary bio-wool harvesting process (Bioclip) became available. This technique relies on an artificial epidermal growth factor which when injected into sheep interrupts hair growth. A month later, breaks appear in the wool fibre and the fleece can be pulled off whole, without the use of mechanical hand piece, in half the normal shearing time. Wool harvested using this process will be free of second cuts and skin pieces contaminating the fleece (Gupta, 2001).

## 3) Aquaculture industries

Reproductive biotechnology in fisheries provides opportunities to increase growth rates and improve the management of farmed species and to limit the reproductive potential of genetically engineered species. The large size and hardy nature of many fish eggs allow them to be manipulated easily and makes it possible for gene transfer by direct injection of a foreign gene or by electroporation, in which an electric field assists gene transfer (Khan et al. 2017)

Sex-reversal and polyploidy technologies are beginning to have an impact on fish production. These technologies are on the threshold of advancing global food security significantly, and will be rapidly adopted and applied in both developed and developing countries. Several examples of the successful application of triploidy exist in aquaculture. Triploid salmon, trout, grass carp and Pacific oysters are commercially produced (Dunham, 2004)





## 4) Livestock industries

Advancement in artificial insemination (AI) and multiple ovulation followed by embryo transfer (MOET) have already had a major impact on livestock improvement and development programs in developed countries and many developing countries because they trigger up the process of genetic improvement, reduce the risk of disease transmission and expand the number of animals that can be bred from superior parents (McCullough et al., 2008).

Advanced biotechnology based diagnostic tests make it possible to identify disease causing agents and to monitor the impact of disease control programmes to a degree of precision not previously possible. Enzyme-linked immunosorbent assay (ELISA) tests have become the standard methodology for the diagnosis and surveillance of many animal and fish diseases worldwide (Khan, 2017)

Genetically engineered vaccines are being developed to protect livestock against pathogens and parasites. Recombinant vaccines can offer various advantages over conventional vaccines in terms of safety, specificity and stability. Today, quality improved vaccines are available for Newcastle disease, classical swine fever and rinder pest (Cordell et al., 2009).

## 5) Pulp and paper industry

The pulp and paper industry is traditionally known to be a large contributor to environmental pollution due to its large consumption of energy and chemicals. Biotechnological methods, however offer potential opportunities for changing the industry towards a more environmental friendly with efficient operations compared to conventional methods. Biotechnological methods are environmentally less deleterious processes and can be used to replace the non-biological processes. Biotechnological processes increase the pulp yield, improve fiber properties, enhance paper recycling, reduce processing and environmental problems and are energy efficient (Bajpai, 2012).

Biotechnological applications that have been transferred to commercial use in the pulp and paper industry include Xylanases for bleach boosting; cellulose for improved drainage; lipases for pitch removal; cellulose-hemicellulase mixture for de-inking and fiber modification; esterases for stickies control; and levan hydrolases, proteases, cellulases amylases for slime removal (Bajpai, 2012).






## 6) Pharmaceutical industry

Agricultural biotechnology can also be used to develop medicines and vaccines in the pharmaceutical sector (Sun, 2008). This is because research has shown that agricultural biotechnology can be used to introduce high value compounds in plants, such as PHB granules in Arabidopsis mesophyll cell nucleus, which compounds can then be used in the pharmaceutical industry in the production of drugs and vaccines (www.blog.mixerdirect.com). Research has already led to the production of vaccines for diseases like rotavirus, cholera, rabies among others (Concha et. al. 2017), and it is projected that further development of this line will reduce costs of production for pharmaceutical industries as their raw materials will be more abundant. Definitely as production becomes easier and cheaper, more people will be involved; more so in the developing world where the traditional production mechanisms have been quite prohibitive because of complexity and high costs. This will in turn lead to industrial development.

Building a chain of inter-related benefits, the increased crop yield boosted nutrient-content in crops and more abundant medicines can in turn be used to improve the health, well-being and productivity of industrial labor force. This owes to the fact that increased crop yields will avail more food to industrial workers to sustain them in the production process, while production of nutritious foods and medicines will help reduce their proneness to diseases caused by poor nutrition. Abundant medicines will help them get properly treated for whatever illness might attack them. This will mean less absenteeism due to sickness, more efficiency because of sufficient body strength, among others.




## 7) Energy industry

Agricultural biotechnology can also be used to spur industrial growth by employing it for the production of more abundant, more efficient and more affordable bio-fuels used in running industries. Bio-fuels are increasingly becoming a more reliable and more affordable energy source for industries (www.blog.mixerdirect.com), especially in the developing world where other power sources can be unreliable or very expensive, and this makes agricultural biotechnology a handy solution since the agricultural industry plays a role in the biofuels industry, providing feedstocks for the fermentation and refining of bio-oil, bio-diesel and bio-ethanol. Already it has been established that high-yielding, energy-dense crops can minimize relative costs associated with harvesting and transportation (per unit of energy derived), resulting in higher value fuel sources than most other alternative energy sources. Ongoing research is furthering the prospects

of bio-fuels as high value fuel sources courtesy of the way genetic engineering and enzyme optimization techniques are being used to develop better quality feedstocks for more efficient conversation and higher British Thermal Unit (BTU) outputs of the resulting fuel products.

## 8) Environmental management industry

Lastly but not least, agricultural biotechnology can be used to produce crops that reduce the industrial footprint on the earth. Some genetically-modified crops have been engineered to reduce the amount of pesticide usage and cause tillage changes that have reduced the release of greenhouse gas emissions from such substances as carbon-dioxide, carbon-monoxide, among others, from the agro-industry (Brookes and Barefoot, 2016). A good example is the Herbicide Tolerant Soybean produced in the U.S that reduces the need for weeding. More effort towards the development and cultivation of such crops will promote industry by cutting its negative side effects on the environment.



## 9) Mining industry

For mining industries, hyper accumulators (plants that absorb heavy metals in high concentrations, accumulate and translocate them to the shoots) can be developed through agricultural biotechnology, and these plant species do Phyto-mining. Phyto-mining aims to generate revenue by recovering marketable amounts of metals from plant biomass (bio-ore) through use of plants to mine valuable heavy metals from contaminated or mineralized soils. A pioneer Phyto-mining study has been carried out using the Nickel hyperaccumulator S. polygaloides and a yield of 1000kg-1 of Sulphur free Nickel (Ni) can be obtained. Such hyper accumulators can be engineered to act as reliable indicators of the presence of minerals for mining and these are called excluders. These signs can be seen during the plant's growth.

Agricultural biotechnology generates new technology that allows farmers to reduce their costs of production, and as more farmers adopt the technology, they start to push down prices of the product, and the benefits of lower prices are passed along to consumers. This means there will be more demand from the rural sector for agricultural inputs and consumer products, hence industrial development.



Figure: Copper contaminated land in Kilembe, Kasese district



## Conclusions

Agricultural biotechnology will lead to an expansion of the manufacturing sector as explained above. If agricultural biotechnology is prohibited in developing countries, opportunities for industrial sector development, together with reducing poverty, food insecurity, child malnutrition, and natural resource degradation will be missed. The productivity gap between developing and developed country agriculture will widen. Therefore, agricultural biotechnology must be viewed as one element in a comprehensive sustainable, industrial development, poverty alleviation strategy focused on broad-based agricultural growth, not a technological quick fix for economic development and world hunger eradication.


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