EDITORIAL

Biotechnology and Health in Africa: Challenges and perspectives

INTRODUCTION

Biotechnology, which is defined as "all lines of work by which products are produced from living organisms" has come of age and now manifested itself as an indispensable component of the life sciences affecting health, agriculture, and the environment. Biotechnology is also at the basis of a burgeoning service industry with a multi- billion dollar annual turnover. [2,11]

Perhaps, the greatest advances of biotechnology have been in the domain of human health where a new generation of vaccines, diagnostic, and therapeutic products have been produced. The development of high yield and disease resistant plants are among the most glaring achievements of biotechnology in the domain of agriculture and nutrition. Virtually all the important food crops (rice, maize, banana, manioc, tomatoes etc) have been modified for greater performance with the help of modern biotechnology. [1, 2, 11]

Despite its outstanding achievements, biotechnology has also stirred a lot of controversy in the popular and scientific press. Whilst optimists see biotechnology as a panacea for the world's health and food problems, others are unduly concerned by its potential devastating consequences. Vivid debates about human cloning, seed terminator technology, genetically modified organisms, bio-terrorism have led governments to enact laws which in some cases threaten to block or retard scientific growth in this domain. [11]

The present report will focus on biotechnology as it applies to health in Africa. Herein we opine that biotechnology is an effective tool, which can be harnessed to alleviate Africa's scourges such as HIV/AIDS, malaria, tuberculosis, and other endemic diseases. To fully benefit from these advances, Africa must not become a mere consumer of biotechnology products, but must develop indigenous capacity through training, research and development to produce at least some of her biotechnological goods and services. Before elaborating on these themes it is pertinent, for the sake of clarity to further define biotechnology.

The definition and scope of biotechnology[2]

In the introductory statement, I gave a rather early definition of biotechnology as Karl Ereky, the scientist who coined the term, first defined it. Today, many definitions of biotechnology abound[2]. These definitions carefully crafted, as they are, fail sometimes to reach the common man. However if in our daily activities we use plants, or animals, or their parts to produce goods or change our environment, we are engaged in some form of biotechnology.

The most ancient type of applications has come to be known as *classical* or *intermediate* biotechnology, which revolves round the manipulation of existing organisms for industrial production. The beer brewer employs existing cereals and yeast in the fermentation process that yields his final product. The wine maker is satisfied with existing varieties of grapes, and yeast to manufacture the numerous varieties of wine. Analogous assertions can be made about bread baking and the transformation of milk to various products. Even if we look further to plant and animal breeding, it is easy to see that breeders cross existing strains to obtain improved offsprings with the desired characteristics.

It is generally accepted that classical biotechnology covers fermentation, animal and plant breeding, vaccine production, natural products chemistry, *in vitro* culture and propagation of plant cells etc. For the improvement of varieties, the classical biotechnologist crosses the parents thereby bringing together their entire genetic blueprints in the hope that the desired characteristics would be inherited according to the laws of Mendel. There is no direct intervention at the genetic level to select what trait is needed and deliberately introduce it into the desired organism. Rather the classical biotechnologist (or breeder) relies on the natural process of reproduction, which can be long and unpredictable.

Modern or advanced biotechnology strives to design and then create new organisms with greater performance capabilities through a modification of their genetic constitutions. The hall mark of modern biotechnology is, therefore, the ability to determine at the level of the *body's blueprint* the particular trait that is desired, cut it out and then transfer it to an entirely different organism where it would now appear as a new trait. It is now well known that the genetic blueprint is the deoxyribonucleic acid, DNA (or ribonucleic acid RNA, in some viruses), which resides in all living organisms. Even simple organisms like viruses and rikettsia (or primitive bacteria) contain nucleic acids. The particular genetic trait that is inheritable has over the years been known as the *gene* (which today is defined more precisely than Mendel did). Modern biotechnology therefore has come to be known as *genetic engineering* (because of the elements of design and construction embodied in its practice). *Recombinant DNA technology, gene manipulation,* etc. are other synonyms of genetic engineering.[13]

Some Land Marks in the Historical Development of Biotechnology[3, 13]

Classical biotechnology dates as far back as the antiquities when the ancient Egyptians and Babylonians first developed fermentation technologies for brewing, wine making and baking. Modern biotechnology is however more recent. Its official birth-decade is in the 1970's when the first *gene cloning* experiments were conducted and the first *monoclonal antibodies* produced. However, major advances in molecular biology and genetics preceded these developments. In the 1940's Macleod and colleagues demonstrated that deoxyribonucleic acid (DNA) is the genetic material. In 1953, Watson and Crick determined the structure of DNA and set the stage for the rapid expansion of molecular biology. In 1977, Sanger and Coulson in Britain and Maxam and Gilbert in USA independently developed methods of the rapid sequencing of DNA.

The 1980's can be described as the decade of the cloning boom, which culminated in the development of the polymerase chain reaction (PCR) for the amplification of DNA, the creation of transgenic animals and plants, etc. By the end of the 1990s, plans for the sequencing of the human genome were well advanced. In 1997 Scottish scientists cloned a sheep from somatic cells raising a worldwide debate on the cloning of the human beings. In 2000 the draft human genome was published. Today the genomes of more than fifty organisms have been sequenced. The analysis of this vast repository of genetic data has given birth to the science of Bioinformatics and the allied disciplines of Genomics and Proteomics.[3, 7]

HEALTH ISSUES AND BIOTECHNOLOGY IN AFRICA

The Disease burden of Africa[6, 12, 14]

Africa notoriously leads the world in the damning statistics of contemporary scourges. The HIV/AIDS pandemic, which was first diagnosed in America in the early 1980's, has expanded dramatically in Africa[12]. Of the 36 million infected with the deadly disease, 26 million reside in Africa. Malaria, which affects 200 million people world-wide, killing 1 - 2 million a year, most of them African children is well known. Tuberculosis, a disease of the poor has re-emerged in Africa and other parts of the world as a result of weakening of immune system by HIV/AIDS, worsening economies and spread of drug resistance.

Apart from the major diseases mentioned above, virtually all of the major diseases recognised by the WHO (TDR as principal causes of economic backwardness are prevalent in Africa [table 1]). Preventable childhood diseases such as, infectious diarrhoea, whooping cough, poliomyelitis, measles etc. still kill African children. The emergence and spread of resistance to common antibiotics, anti-malarial drugs and insecticides has complicated the implementation of disease control strategies.

As if the burden of infectious/transmissible diseases was insufficient, the so-called diseases of the rich are invading the African health scenario as well. Cancer, diabetes, cardiovascular diseases are on the increase among Africa's newly urbanised population with modernised life styles and nutritional habits[6].

The up-surge in disease burden poses great strains on the weak economies of African countries. Obviously new approaches are required to address the African health situation. Biotechnology offers excellent opportunities, which can be successfully employed in a multi- disciplinary context to cope with Africa's health debacle. The rest of this article will highlight some of the applications of biotechnology that are relevant to health issues in Africa.

Diagnostic tools of Biotechnology.

Three major tools, namely, *gene probes, monoclonal anti-*

bodies and *gene amplification* constitute the main stay of contemporary molecular diagnosis, which have been employed for the diagnosis of systemic and transmissible diseases of man, animals and plants with high precision and sensitivity. In many cases the techniques based on these tools surpass classical methods based on microscopy and clinical history. For the sake of clarity, we would dwell briefly on the principles involved, and illustrate them with a few of the important diseases of Africa.

Gene Probes[8]

A gene probe is a specific segment of an organism's deoxyribonucleic acid (DNA) specially labelled with a radioactive tracer or marker molecules. When this probe is hybridised (united) with the DNA of target organisms, it can be localised with help of a tracer/marker, thereby confirming the presence of the target organism. Gene probes have been developed for bacteria, viruses, parasites including *P. falciparum, O. volvulus*, schistosomes, etc.[14] The use of probes requires that the sufficient DNA be available from target organism and this is not always easy. Consequently, gene amplification techniques have been developed and are gradually taking over from gene probes.

Gene Amplification[8]

The polymerase chain reaction (PCR) is now a household word in the life sciences. This reaction allows minute quantities of DNA (as small as from a single cell) to be amplified using a cyclic reaction sequence into chemically significant amounts. (The mechanism of this reaction, which can be found in any standard textbook of Biochemistry falls beyond the scope of this review). Demonstration of a pathogen's DNA fragments is taken as evidence of its presence in the specimen. PCR methods have been devised for both systemic and transmissible diseases and employed for speciation and polymorphism studies. They surpass traditional methods in sensitivity, equal them in specificity, but can be more expensive and technically demanding than traditional methods of diagnosis. Furthermore, most PCR protocols do not yield quantitative results, which are some times required for effective clinical management.

Monoclonal Antibodies[5]

Since the invention of hybridoma technology by Kôhler and Miltstein, monoclonal antibodies have played a crucial role in research, diagnosis and treatment of diseases. In a typical scenario spleen lymphocytes are harvested from a mouse immunised with a desired antigen and then fused with transformed cells *in vitro*. The hybrid cell which is capable of dividing *in vitro* indefinitely (in contrast to the lymphocyte that was employed in the fusion) then produces antibodies directed to specific epitopes of the antigen. These antibodies are termed *monoclonal* because they are derived from a single lymphocyte clones. By contrast a *polyclonal antiserum* is derived from several lymphocyte clones that have been sensitised by the different epitopes on the target antigen.

Monoclonal antibodies when carefully selected can be highly specific and certainly can be produced in large amounts under standardized conditions. Monoclonal antibodies have been employed in the detection of virtually all-important pathogens (bacteria, viruses, parasites, rikettsiae etc).

New drugs and vaccines from biotechnology[7]

Since the early development of recombinant insulin and hepatitis B vaccine, the portfolio of therapeutic agents that are manufactured with the help of biotechnological methods has increased dramatically. Currently employed HIV/AIDS drugs directed against protease inhibitors were created thanks to the methods of biotechnology and synthetic chemistry. Growth hormones, interferons and enzymes employed in the treatment of cancer, cystic fibrosis and other systematic disorders could not have been created without the help of biotechnology.

Drug discovery has gained additional impetus from biotechnology and new disciplines of Bioinformatics, functional genomics and proteomics.[7] Typically a drug target, often a protein is identified employing a variety of high-through-put screening procedures. This protein is cloned and expressed using recombinant DNA technology. Large-scale production that is required for structure determination is done with the help of biotechnological methods. Once produced in large amounts, the protein can be crystallized for x-ray crystallography, a sophisticated method that can be used to elucidate the 3-dimensional structure of the target protein. Once the 3-D structure of a potential target is known, inhibitors can be designed to this target. Such inhibitors are prototypes of rationally designed drugs. Thus the integration of biotechnology, genomics and structural biology provide a formidable platform for the discovery of new drugs for the treatment of human, animal and plant diseases.[1, 7]

Plant derived medicines[10, 15]

African peoples in their vast majority continue to rely on plants as a source of medicinal preparations against a variety of ailments. Higher plants have provided more than 25% of prescription drugs currently in use.[10] African's flora consequently represents a rich resource that can be profitably tapped for cures against the many devastating diseases that threaten the population.

In fact laboratories across Africa are actually engaged in the exploration of plant products for cures against drug resistant malaria, HIV/AIDS, bacterial and fungal infections as well as systemic disorder such as cancer, diabetes and mental illnesses.[15] As a result of these efforts large numbers of new compounds have been isolated and characterised. However, only few of them have been developed to prescription drugs.

We believe that it is necessary to restructure the study of medicinal plants from mere chemical data collection into a rational process that would lead to new drugs for the treatment of endemic diseases. Such an endeavour can benefit from the methods of biotechnology. For example, *in vitro* cultures of plant organs can be employed to generate useful metabolites from rare plant species. The high-through-put methods of biotechnology can be employed to screen for new compounds with interesting activities. The aim of such experiments will be either to validate and recommend existing plant preparations for use as nutrichemicals, or to develop the plant products into drugs following the standard (though lengthy and costly) methodology.

Capacity building

Unless their human and material resources are developed, it will be impossible for African countries to fully benefit from the advances in biotechnology. Several lines of action can be envisaged which include but are not limited to the following: -

- Strengthening of existing centres of excellence and creation of new ones.
- Organisation of short-courses/workshops and degree programs in biotechnology.
- Incorporation of biotechnological procedures into our production processes.

Excluding South Africa, which is rather advanced, a few centres of excellence exist in Africa with considerable expertise in biotechnology. In Kenya, the International Livestock Research Institute (ILRI), The International Institute for Insect Physiology and Ecology (ICIPE) and the Kenya Medical Research Institute (KEMRI) are examples of well-equipped institutes with considerable skills in health biotechnology. In Franceville, Gabon; Yaounde and Buea, Cameroon, biotechnology laboratories exist and are carrying out work on malaria and filarial diseases. It will be important to strengthen these and other laboratories through up-grading their staff and equipment.

The final objective in the training must be to enable African biotechnologists to produce some of their required goods and not just to be passive users of imported biotechnological products. This would be possible if venture capitalists invest on prototype factories to produce, on African soil with help of biotechnology, diagnostic kits, enzymes, vaccines and drugs, etc.

Networking and collaboration within and between countries is crucial for creating the critical mass of scientists necessary to make a breakthrough in this vital domain. In this regard the African Biotechnology Association, the Federation of African Societies of Biochemistry and Molecular Biology, and other regional organisations need to be strengthened and supported.

RESEARCH OPPORTUNITIES

Biotechnology research in Africa should address the felt needs of the continent and should aim at rendering Africa increasingly self sufficient in the production of its health care products. The following areas merit attention.

1. Diagnostics

Simple, sensitive, specific and affordable diagnostic methods for HIV-AIDS, malaria, tuberculosis and other endemic parasitic infections are still needed. Priority should be given to methods that can be easily performed in the rural areas of Africa with limited or no laboratory facilities. The mapping of drug resistance against pathogens should be given some attention as well.

2. Bioreagents

Development and small-scale production in Africa of critical biotechnology reagents for use in research, teaching and diagnosis should be encouraged. Such reagents may include enzymes, monoclonal antibodies, gene probes etc.

3. Vaccine Development

The identification and testing of candidate vaccine molecules for endemic diseases including HIV/AIDS, malaria, tuberculosis, onchocerciasis and the childhood infections are important research topics requiring urgent financial support. Local production and quality control of essential vaccines should also be undertaken in Africa.

4. Plant derived medicines

Pre-clinical studies and validation of bioactive substances form medicinal plants, traditional formulations for use as nutrichemicals and other plant derived medicines deserve greater attention. Priority should also be given to plant derived drugs for the major infectious diseases and emerging systemic disorders including HIV/AIDS, malaria, tuberculosis, onchocerchiasis, trypanosomiasis, cancer, diabetes and mental disorders.

PERSPECTIVES

Protection and sustainable use of Africa's biodiversity.

The Rio Convention of 1990 and the Cartagena Protocol of 2000 defined the conditions for the protection of the environment, biodiversity and safe use of biotechnology. Many African countries have signed this convention, and some of them (South Africa, Nigeria, Cameroon, etc) have already drawn up biotechnology action plans. Of major concern are questions relating to the transfer of Genetically Modified Organisms (GMOs), including modified food crops, which can be introduced into Africa. Whilst GMOs are more or less accepted in the USA, they have been vigorously rejected in Europe. African countries still have to take a stand on this issue since genetically modified foods can have an impact on health.

Ethical Issues

An international controversy is currently raging on whether or not biotechnology methods should be used to clone human beings. The USA has enacted legislation banning human cloning. In the European Union reproductive cloning has been proscribed, but the therapeutic cloning seems to be accepted in some countries e.g. Britain. What is the stand of African countries to these important issues? The question of bioterrorism has received international attention in the aftermath of the September 11, 2001 attack on New York. Health biotechnologists in Africa need to follow this debate carefully and make appropriate recommendations to their respective Governments. In this regard the Rio Convention takes on additional significance as a guiding principle.

Biotechnology and poverty alleviation

A healthy population is an absolute requirement for the economic development of any country. We have summarized above the dismal health situation of African countries. Biotechnology can provide valuable solutions in the area of diagnosis, development of new drugs and vaccines against the endemic diseases of Africa. Plant derived drugs are likely to be cheaper than synthetic ones, which take hundreds of millions of dollars to develop. Similarly diagnostic kits created in Africa could sell for competitive prices considering the low cost of labour in Africa.

The creation of Biotechnology companies can provide jobs and foreign currency revenue. Although biotechnology is not a panacea, it is a vital asset that cannot be ignored in any successful health care scheme.

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