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Critical Reviews: Biotechnology and Sustainable Industrialisation for National Development

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Authors' contributions

This work was carried out in collaboration among all authors. Authors CCE and OJO designed the study, performed the statistical analysis, managed the literature searches, wrote the protocol and wrote the first draft of the manuscript. Author AVN managed the analyses of the study. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

This study aims to educate people about biotechnology and its role in the socio-economic advancement and development of a nation so that they can make informed choices. There is a growing appreciation that nationally, regionally and globally the management and utilisation of natural resources need to be improved and that the amounts of waste and pollution generated by human activity need to be reduced on a large scale. Economic growth provides jobs and income, goods and services and opportunities to improve the standard of living for an increasing world population. It is evident from various reports that, over the years, the requirement of biomass for food, fodder and fuel has been responsible for different types of environmental problems like deforestation, eutrophication, contaminated agricultural fields, etc. The eco-efficiency of industrial bio-products and bioprocesses can provide a basis for moving a broad range of industries toward more sustainable production. However, these applications are occurring as a "thousand points of light", that is, without a guiding principle or a strategic orientation. It is concluded that biotechnology occupy a very strategic position in the socio-economic advancement and development of the nation in particular and the world at large. Investments therefore should be made on more

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sustainable and renewable raw materials – a bio-based economy rather than the conventional or the traditional methods so as to provide a cleaner and healthier environment.

Keywords: Biotechnology; industrialization; bio-products; utilization; development.

1. INTRODUCTION

Human activities such as industrialisation, urbanisation, agriculture, fishing and aquaculture, forestry and silviculture as well as petroleum and mineral extraction have profound impacts on the world's environment as well as on the quality of life. The result of this impact has led to a growing need for global management and utilization of natural resources need to be improved as well as reduction in the waste generated by humanactivities. For this to occur there is need for reduction and elimination of un-sustained patterns of production and consumption. Hence, there is a growing interest on industrial sustainability so as to bring about reduction of the environmental impact and improving quality of life. This will require a reduction and, if possible, elimination of unsustainable patterns of production and consumption [1].

The industrial sectors that derive their raw material and/or key components from natural resources and biological processes constitute the bio-based economy or bio-economy[2].

Biotechnology is any technique which involves the application of biological organisms or their components, systems or processes to manufacturing and service industries make or modify products, to improve plants or animals or to develop micro-organisms for special uses [3,4]. Biology, technology, and human-directed genetic change have been a part of agriculture since the beginning of cultivated crops some 10,000 years ago. Biotechnology has, in a general sense, been used as a tool for food production since the first breeders decided to selectively plant or breed only the best kinds of corn or cows. Technology is a tool we use to achieve a goal, such as improved food quality [3,4,5].

Scientific advances through the year have relied on the development of new tools to improve socio-economy such as health care, agricultural production, and environmental protection. Individuals, consumers, policymakers, and scientists must ultimately decide if the benefits of biotechnology are greater than the risks associated with this new approach [3]. The technology tools used in biology have changed rapidly since scientists moved the first specific gene from one organism to another in 1973. This new era began in 1953 when scientists James Watson and Francis Crick determined the structure of DNA [3,4]. DNA determines the features and characteristics of all living organisms: plants, animals, and microorganisms. Once scientists understood how DNA was put together, they could determine which parts of the DNA (genes) are responsible for certain traits [3,5]. Genes determine traits by controlling the production of proteins, including enzymes. Proteins and enzymes are used by all living organisms to grow, metabolize energy, and become what their genetic code dictates. Each cell of an organism contains the entire genetic code needed to create the organism. The interaction of genetic makeup and environmental factors shapes the nature of all living things. At the heart of food production is biotechnology.

One aspect of biotechnology which has been used for centuries is the selective breeding of crop plants and farm animals to produce improved food. Another is fermentation, in use for millennia to produce fermented foods like cheese, bread, beer, sauerkraut and sausages [3,5]. The transition from a dependence on fossil fuels to using of agricultural products as not just for providing food security but also biomass as a renewable raw material for industry will be the basis of the integrated bio-economy [2]. In recent years, biotechnology is revolutionizing industrial and agricultural practices by improving quantity and quality of products. In addition, the number of commercial biotechnologyproducts is increasing each year [6].

This overview seeks to provide science-based information about discoveries in biotechnology as it affects mankind and is designed to help us understand and assess the risks and benefits of biotechnology. It also provides information about biotechnology with examples of how these new tools of biology and agriculture are used in food production as part of socioeconomic advancement and national development. It includes a perspective showing how biotechnology fits into the history and future of science and food for mankind. Its purpose is to educate people about biotechnology and its role in the socio-economic advancement and development of a nation so that they can make informed choices.

2. WHAT Is INDUSTRIAL SUSTAINABILITY?

The World Commission on Environment and Development [7] has provided insight on sustainable patterns of production and consumption through its description of sustainable development:

> "Sustainable Development: *Strategies and actions that have the objective of meeting the needs and aspirations of the present without compromising the ability to meet those of the future*".

This definition of sustainable development has provided a conceptual definition of industrial sustainability:

> *"Industry is sustainable when it produces goods and services in such a manner as to meet the needs and aspirations of the present without compromising the ability of future generations to meet their own needs".*

3. ADVANCES IN SPECIFIC AREAS OF FOOD PROCESSING

3.1 Improved Food Ingredients

Necessary changes to the key food ingredients, starches and oils, are usually made by processing. Biotechnology opens up the possibility of altering crop plants to produce exactly the type of ingredients needed

3.1.1 Starches

Plant breeders have introduced a bacterial gene into potato plants which increases the amount of starch in the tubers with less water content.. Sweeter potatoes have also been produced which have higher sugar content than traditional varieties.

3.1.2 Oils

Rapeseed and sunflower are being altered to produce more stable and nutritious oils, which contain linoleic acid instead of linolenic acid and have lower saturated fat content. Rapeseed has also been modified to produce a high-temperature frying oil slow in saturated fat [3,8,9,10]

3.2 Product Quality

Biotechnology is being applied to change some characteristics of certain raw materials so that they can be better appreciated by the consumers. Biotechnology researchers are increasing the shelf life of fresh fruits and vegetables; improving the crispness of carrots, peppers and celery; creating caffeine-free coffee and tea; extending the seasonal geographic availability of tomatoes, strawberries and raspberries; improving the flavor of tomatoes, lettuce, peppers, peas and potatoes; and creating seedless varieties of grapes and melons. Japanese scientists have now identified the enzyme that produces the chemical that makes us cry while slicing an onion. Knowing the identity of the enzyme is the first step in finding a way to block the gene to create "tearless" onions [3]. Much of the work on improving how well crops endure food processing involves changing the ratio of water to starch. Potatoes with higher starch content are healthier because they absorb less oil when they are fried, for example. Another important benefit is that starchier potatoes require less energy to process and therefore cost less to handle. Many tomato processors now use tomatoes derived from a biotechnology technique, somaclonal variant selection. The new tomatoes, used in soup, ketchup and tomato paste, contain 30 percent less water and are processed with greater efficiency. Another food processing sector that will benefit economically from better quality raw materials is the dairy products industry[3].

3.3 Safety of the Raw Materials

Any biotechnology product that reduces microbes found on animal products and crop plants will significantly improve the safety of raw materials entering the food supply. The most significant food-safety issue food producers' face is microbial contamination, which can occur at any point from farm to table.Improved food safety through decreased microbial contamination begins on the farm. Transgenic disease-resistant and insect-resistant crops have less microbial contamination [10]. New biotechnology diagnostics can detect microbial diseases earlier and more accurately, so farmers can identify and remove diseased plants and animals before others become contaminated [3]. Biotechnology is improving the safety of raw materials by helping food scientists to discover the identity of the allergenic protein in foods such as peanuts, soybeans and milk, so they can then remove them. With biotechnology techniques, great progress are been made in identifying these allergens. More importantly, scientists have succeeded in using biotechnology to block or remove allergenicity genes in peanuts, soybeans and shrimp [3,9]. Finally, biotechnology is helping us improve the safety of raw agricultural products by reducing the natural plant toxins found in foods such as potato and cassava [3].

3.4 Biotechnology Applications in Production of Food Ingredients

Flavoring agents, organic acids, food additives and amino acids are all metabolites of microorganisms during fermentation processes. Microbial fermentation processes are therefore commercially exploited for production of these food ingredients. Metabolic engineering, a new approach which entails the targeted and purposeful manipulation of the metabolic pathways of an organism so as to achieve a desired product, is being widely researched to improve the quality and yields of these food ingredients. It typically involves alteration of cellular activities by the manipulation of the enzymatic, transport and regulatory functions of the cell using recombinant DNA and other genetic techniques. Understanding the metabolic pathways associated with these fermentation processes, and the ability to redirect metabolic pathways, can increase production of these metabolites and lead to production of novel metabolites and a diversified product base [5].

3.5 Promising Crop Plants

3.5.1 Improved nutritional value

Crops in development include 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 betacarotene, a precursor of vitamin A; and crop plants with a modified fatty acid profile. An example is a strain of oilseed rape which produces a special type of polyunsaturated fatty acid (the so-called w3-fatty acids). These have been linked to brain development and have potential in a range of specialty, clinical and infant foods [3].

3.5.2 Better flavor

Different types of peppers and melons with improved flavour are currently in field trials. Flavour can also be improved by enhancing the activity of plant enzymes which transform aroma precursors into flavouring compounds [3].

3.5.2 Improved keeping properties

There is improved keeping properties with the aim of making transport of fresh produce easier, giving consumers access to nutritionally valuable whole foods and preventing decay, damage and loss of nutrients. Examples include the improved tomatoes now being sold in the US, and recently approved in the UK, which have been genetically altered to delay softening. Research is underway on making similar modifications to broccoli, celery, carrots, melon and raspberries. The longevity of some processed foods such as peanuts has also been improved by using raw materials with a modified fatty acid profile [3].

4. BIOTECHNOLOGY APPLICATION In ENVIRONMENT

Biotechnology application to microorganisms for environmental purposes includes bioremediation, biofuels, etc. Bioremediation is often successful and the most inexpensive method, it is only one of many techniques for dealing with hazardous wastes.

4.1 Waste Management

Waste disposal and waste management has become a cause of concern worldwide. In order to move towards a more efficient waste management result, it is required to improve the efficiency of production processes and reuse as much of the raw materials as possible, thus reducing the input of both energy and materials. This could be achieved by recycling reusable materials, replacing non-degradable substances with biodegradable compounds, applying biological extraction methods in mining, redesigning production processes to avoid waste generation and developing efficient and specific monitoring devices [11]. Up till now Biotechnology, has made little contribution to recycling despite its great potential, except in the area of paper recycling. The treatment of aqueous and solid wastes of industrial, agricultural and domestic origin offers a number of opportunities for the application of biotechnological methods. The effectiveness of these methods is based on the ability of the organisms to degrade organic material or absorb hazardous substances [11]. Bacteria [12], microalgae [13], fungi [14], yeasts [15] and plants [16] have been found to degrade organic wastes to some extent, and the fixed costs per cubic meter of bioremediation can be 10-20 times lower than incineration. Composting trials showed that certain pharmaceutical solid wastes can be broken down by 90% in 10 days of biological treatment [17]. It has also been shown that the biotransformation of waste paper to ethanol by recombinant bacteria is cost effective compared with the conventional process using yeast and added enzymes[11].

Treatment of municipal wastewater by activated sludge method was perhaps the first major use of biotechnology in bioremediation applications. Activated sludge treatment remains a dependable technology for controlling pollution of aquatic environment. Similarly, aerobic stabilization of solid organic waste through composting has a long history of use. Both these technologies have undergone considerable improvement [18]. More recently, microorganisms and enzymes have been successfully used in diverse bioremediation applications [19,20,21,22]. Effective and controlled bio-removal of nitrate and phosphate contamination from wastewater has become possible today [23,24]. Overall, the biotechnological methods employed in wastewater treatment are activated sludge, trickling filters, oxidation ponds, bio-filters and anaerobic treatment. Besides, solid waste composting techniques, bio-trickling filters and bio-sorption are the examples of biotechnology applications in environmental engineering. In all these methods, it is essential to use suitable microorganisms that will bring about the degradation of organic substances and complete the treatment process in favourable conditions [25]. The organic wastes present in wastewater are carbohydrates (starch, polysaccharides, lignin, cellulose, and hemicelluloses), proteins-simple and conjugated, lipids (fats, oils, wax, lipopolysaccharides, and lipoproteins), hydrocarbons and organic acids [26]. Different types of microbes use these organic materials as substrates for their growth. Different processes have been developed to use these wastes as substrates for industrial production of alcohol, organic acids, aldehydes, ketones and biogas. Despite the progress made in the development of efficient methods for treatment of wastewater, in most of the cases, it is released into the surface water with partial or no treatments thus deteriorating the surface water quality.

Today, numerous microbial waste processing schemes can be carried out, if not, in a cost-effective manner, but in a sustainable mode by harnessing the bye products generated from the treatment of wastes. For instance, solid and liquid wastes containing high organic substances are used for obtaining methane, thus giving rise to a new source of energy that can be utilized for running the treatment plant. Again, anaerobic microbial degradation of organic wastes generates biogas as the major end product, a vital renewable and alternative source of energy [26].

A hurdle to the international use of bioremediation is the notion, held by many that pollution control costs industry money and makes industry, in its own view, less competitive in world markets [27]. Several Organization of Economic Co-operation and Development (OECD) countries have been carrying out biotechnology research and development (R&D) in order to improve waste treatment, notably the Netherlands, France, Japan, and Germany [27]. Still, research efforts are generally negligible in many countries, and the dissemination of research results into commercial applications is insignificant as compared to other sectors influenced by biotechnology. This is due to weak regulations that support the payment of fines by industry for waste emission rather than the use of systems to reduce or cleanup pollution [28]. Improved and alternative solid waste disposal systems are being suggested to reduce environmental degradation.

Sanitary landfilling has emerged as an environmentally acceptable solid waste disposal method and in many countries such disposal practices form an integral part of urban solid waste management [26]. The quality of landfill designs, based on technical, social, and economic developments have improved significantly in recent years. Design concepts are intended to ensure minimal environmental impacts. The primary environmental concerns connected with landfills are the release of leachates during degradation process and the present landfill technology concentrate on preventing and controlling leachate problems. To minimise the emission of greenhouse gases, the control of landfill gases draws utmost attention. For significant reduction of such landfill emissions in future, the capacity assessment of the landfill to house the biodegradable organic matters is essential. Moreover, mechanical, biological and thermal pre-treatments may be required to achieve better solid waste management. Advanced methods of solid waste management opened up the scope to use these processed wastes as resources to be utilised for various other purposes.

Aerobic composting processes are available to process organic wastes from households, industries, agriculture, horticulture, sludge from the wastewater treatment systems etc. The present composting technology provides efficient composting systems allowing maximum microbial activity in the compost and minimise the loss of valuable resources. Further research is needed to optimize various factors of composting so as to increase the decomposition and degradation processes.

The technique of anaerobic fermentation of wastes is relatively young and unstable. Through research and expenditure, new progress has been made in process development and optimization of anaerobic degradation method of waste treatment. Anaerobic microbial degradation of organic wastes generates biogas as the most important end product which is an alternative source of energy. For industrial scale production of biogas various factors like water content, temperature, pH etc., in the fermentation reactors need optimization as the conditions vary with the ratio of different groups of microbes and the substrates. In order to achieve optimized and uninterrupted biogas production, these factors require special attention in addition to synchronized consecutive degradation steps [26].

Besides, biogas plant effluent makes a useful fertilizer, hence, can increase food production. For markets and councils, removal of food waste reduces health risks associated with disposal onto streets.

4.2 Biological Transformation and Bioremediation

Increase in human activities has led to a significant decrease in the capacity of land. Unsuitable use of agricultural land, poor soil and water management practices, improper crop rotation, poor irrigation practices, use of chemical pesticides, mining activities and entry of acid mine drainage, a wide variety of industrial activities like release of industrial effluents etc., have resulted in changes in global elemental distribution and pollution of aquatic and terrestrial habitats including cropland ecosystems and contributed to wasteland formations. Chemical and biological transformation of metal ions is a dominant process in the environment, which keep the bioavailable metal species under control [26, 29, 30]. Biological transformation involves both microbes and higher plants. It involves the ability of microorganisms and higher plants to transform toxic metal species into non-toxic or less toxic forms. However, progress in biotechnology has provided methods to generate microbial systems or crop types suitable for biotransformation and removal of elements and reclamation of wastelands.

Many plants have been shown to have the capacity to absorb heavy metals, for instance *Thlaspicaerulescen*s (cadmium and zinc), *Zea mays* and *T. rotundifolium* (lead), and Alyssum (nickel) (Chaney *et al*. 1997). The normal accumulation range of plants varies from 0.1 to 100 mg (kg plant mass)-1 while, in exceptional cases it can reach 1-3%, with a record of 25% by dry mass for a nickel-accumulating plant [31]. Such hyper-accumulators are, however, slow grower, have a small biomass and survive best under extreme environmental conditions (e.g. contaminated soils), thus making cultivation difficult [31]. Microbial inoculation (e.g. *Nostoc spp., Cylindrospermum spp., Plectonema spp., Tolypothrix spp., Calothrix spp., Scytonema spp., Plectonema spp., Oscillatoria spp., Anabaena spp., Microchaete spp.* etc.) has also been exercised in localized way in different saline and alkaline soils; and minewastelands to reduce metal bioavailability and to reclaim the concerned site for plantation. Lignocellulolytic and phosphate solubilising microbes in conjunction with lingo-cellulosic organic base (e.g. saw dust, leaf dust etc.) and rock phosphate are applied in mine-spoils to facilitate metal leaching to deeper soil layers and to mobilize metals. There is a wide scope for research and application of biotechnological principles for reclamation of more and more wastelands in view of ever increasing demand for arable land [26,29,30]. The complex nature of crude oil demands the application of various microbial strains [11]. Even though over 30 genera of oil-degrading bacteria and fungi have been identified [32], it is nearly impossible to produce the right microorganism balance for each type of oil[33].

Bioremediation is considered more cost effective than traditional cleaning technologies, with probable savings of 65-85%. Despite justified optimism for future growth, some problems are impeding further progress [11] each waste site has its own unique characteristics, hence, demanding costly special applications; various industrial pollutants cannot be degraded satisfactorily under natural conditions as yet; in situ applications of engineered microbial strains could lead to considerable ecological risks; and, the technique is often time consuming[11].

4.3 Biotechnology in Agriculture

Applications of biotechnology to plants or animals have improved their food processing properties (e.g. development of the FlavrSavr tomato variety, genetically modified to reduce its ripening rate) and the production of proteins from genetically modified (GM) microorganisms to improve plant or animal production (e.g. production of bovine somatotropin (BST), a hormone increasing milk production in dairy cows, by GM bacteria) [3,9]

4.4 Development and Uses of Bio-pesticides

Majority of chemical pesticides and herbicides used by farmers to improve farm yield causes environmental pollutions as the toxic chemicals present in them enter food chains and ecosystems. Microorganisms of various kinds are known to break and modify these complex pesticide molecules and their activities have been shown to diminish the toxicity of xenobiotics [34]. The pesticides with low half-life are less toxic as compared to those with long half-life as degradation processes are increased with long half-life. After release into the environment, the pesticides and herbicides are degraded chemically and biologically thereby minimising the bioaccumulation and environmental effects. The microbial activities tend to convert the xenobiotics into water-soluble intermediates which are then acted upon by primary or secondary group(s) of microbes to form inorganic end-products, resulting in complete biodegradation. Groups of microorganisms which include bacteria, cyanobacteria, fungi, planktonic algae and protozoa are involved in the degradation of pesticides. Some examples of the microbes involved in degradation of pesticides are;*Aerobacteraerogenes, Escherichia coli, Proteus vulgaris, Clostridium ssp., Klebsiellapneumoniae, Pseudomonas flurescens, Nocardia spp., Streptomyces spp., Pseudomonas spp., Acetomonas spp., Acinetobacter spp., Hydrogenomonas spp., Arthrobacter spp., Bacillus spp., Corynebacterium spp., Actinomyces, Rhizobium spp., Streptococcus spp., Xanthomonas spp., Sphingomonas spp., Flavobacterium spp., Erwinia spp., Kurthia spp., Micrococcus spp., Enterobacter spp., Klebsiella spp.,* etc.

Use of chemical pesticides increases the crop production but it is also associated with various environmental problems. To reduce the environmental pollution, it is now encouraged to use biopesticides in addition with chemical pesticides. Bio-pesticides are generally based on bacterial spores, crystal proteins and inert fillers. Thus, the biologically active compounds, dead or living parts of the plants or animals, or the whole plant, animal or microbes applied to control agricultural and domestic pests are called bio-pesticides[26,29,30]. Bio-pesticides generally tend to be highly target specific, do not leave toxic residues, reduce the risk of resistance development in the target species and produce a lesser overall impact on the environment than conventional chemical pesticides [35]. Some of these bio-pesticides are based on *B. thuringiensis*. Some bio-insecticides used commercially in various parts of world are: *Verticillumlecanii* (Commercial in Europe), *Metarhiziumanisopliae* (Commercial in South Africa), *Hirsutellathompsonii* (Commercial in USA), Heliothis nuclear polyhedrosis virus (Commercial in USA) and many more are under field trials (in USA, UK and other countries) for commercial release[36]. Similarly some microbial herbicides are used commercially in USA to control the weeds (e.g. *Phytophthorapalmivora, Colletotricumgloeospriodes*) and some are in experimental state in USA (e.g. *Agrobacterium radiobacter*). Hindustan Lever Research Centre (HLRC) at Mumbai and IARI at New Delhi [36] isolated mutant strains of *B. thuringiensis* (Bt) which produce crystal proteins and form no spores. Bio-insecticides based on these mutants are expected to be ecologically safe and have been successfully tested on insects affecting cotton, maize, cabbage, sunflower etc. Bio-pesticides formulation and application in agricultural fields is gaining momentum in different parts of the world. The variety of bio-pesticides is already plenty and increasing [37,38]. Species of Bacillus and Pseudomonas have been successfully used for seed dressings to control certain soil borne plant pathogens [39]. Besides biologically produced chemicals, pest pathogenic bacteria, fungi, viruses and parasitic nematodes are being developed or used to manage a range of pests. Both spore-forming and non-sporulating bacterial entomo-pathogens are being used or assessed for bio-pesticidal application. Non-sporulating species in the Pseudomonaceae and Enterobacteriaceae families are potential biocontrol agents [18].The spore-formers *B. popilliae* and *B. thuringiensis* (Bt) are already well established insecticides [18]. Thus, optimization of production, multiplication (of living bio-pesticides) and extraction (for bioactive products), and logistical development for commercial production of bio-pesticides require extensive funding and, research and extension. The real sustainable pest management can be achieved through the adoption of the concept of 'integrated pest management' (IPM), which encompasses different bio-control means and traditional methods, such as alternating crops, growing different plant species together, creating refuges and using agrochemicals in moderate amounts[40,41]. The aim of IPM is not to annihilate plant pests but to establish a system of coexistence. It has already shown promising results in Europe and in developing countries [40,41]

4.5 Development and Use Of Bio-fertilizers

Bio-fertilizers are the fertilizers derived from biologically active products or microbial inoculants of bacteria, algae and fungi (singly or in combination), which help in biological nitrogen fixation for the benefit of the plants or otherwise improve the fertility of the soil [26, 29,30].

Increased use of chemical fertilizers has resulted in significant damage to environment. Use of bio-fertilizers is both economical and environment friendly. Increased use of bio-fertilizers is expected to contribute significantly to reducing pollution, energy and resource consumption associated with the use of conventional fertilizers [18]. The prospects for such biological fertilizers are very promising. Vermicomposting has emerged as a new technology for the production of commercial compost from biological wastes such as vegetable or food waste, bedding materials and such other resources, and are utilized as eco-friendly manure in the agricultural field. The normal vermiculture technology depends on the natural degradation efficiencies of earthworm, fungi, thermophilic and mesophilic bacteria which coexist in a composting bin forming a degradation system enabling the organisms to act together on the substrate [26]. With water-soluble nutrients, vermicompost is an excellent, nutrient-rich organic fertilizer and soil conditioner [42]. Large-scale vermicomposting is practiced in Canada, Italy, Japan, Malaysia, the Philippines, and the United States [43]. In India, most of the production of bio-fertilizers is being done in the public sector by research institutions, universities and the National Bio-fertilizer Development Centre. A few state and co-operative fertilizer units also have ventured into this field. Surprisingly, the involvement of the private sector is extremely limited in spite of it being a low investment and high benefit technology.

4.6 Industrial Biotechnology

Fermentation is a very important aspect of many industrial applications involving theprocessing of biological material. Genetic and protein engineering have allowed the development of more efficient microbes and thus contributed to further increases in microbial production.

There is a great importance of fermentation industry to production of consumer goods and services from the direct application in processing (such as in foods and beverages) to the production of fermentation derived fine chemicals such as amino acids, vitamins, alcohols, polysaccharides, and antibiotics mostly by the food and pharmaceutical industry[2].

Enzyme bio-catalysts is another major biotechnology with wide industrial application. Categories of industrial enzymes includes: detergent enzymes, technical enzymes, food enzymes and feed enzymes [2]. Food enzymes derived from gene technology have been on the markets since the 1990s. Within the group of food enzymes, those for milk and dairy dominate the market. The technical enzymes segment is further divided into textile enzymes, leather enzymes, pulp and paper enzymes, fine chemicals enzymes, fuel ethanol enzymes and others [44].

Feed enzymes are added toanimal feed to increase the digestibility of nutrients and to degrade components of the feed that can be harmful or of little or no value. This leads to greaterefficiency in feed utilization [45]. In addition, their use has a positive impact on the environment by reducing fecal nutrient level applied to land, controlling pollution. Europe is the highest consumer of feed enzymes, especially in the poultry industry. Among developing countries, Asia-Pacific is the fastest growing region. This is mainly due to the increased awareness among the farmers about the benefits of enzymes and simultaneous growth in adoption [2].

4.7 Industrial Biotechnology and Health

The medical and healthcare industry is one of the most important sectors of the world's economy. Growth of the biotech industry is mainly due to the applications in the healthcare industry, which have increased the development of health care products, diagnostic services, biopharmaceuticals and relatedproducts[2].

Recombinant-based technology or genetic engineering that allows the modification of large complex molecules, has been applied in the pharmaceutical industry since the 1970s, resulting in the development of a wide range of treatments. These include human insulin with different rates of action, antibody-based novel cancer therapies, interferons for the treatment of viral infections and a range of therapies for noncommunicable diseases such as multiple sclerosis and rheumatoid arthritis [2].

Biopharmaceuticals generated by modern molecular biology are the fastest-growing part of the pharma industry. The number of biotechnological drugs has increased exponentially in the last three decades[2]. In the USA alone, the FDA has approved 34 monoclonal antibodies, 26 enzymes or enzyme modulators (e.g. dornasealfa, alteplase, reteplase) and 31 modulators of receptor function (e.g. insulin, interferon alpha-2a, erythropoietin [46].

The contribution of biotechnology to the health industry is not only about the production of biotherapeutics. Genetic engineering and recombinant protein production is essential for the generation of diagnostic systems for viral infection and genetic disorders so as to properly diagnose these disorders. The latter field has benefitted greatly from the information generated by the genome sequencing projects.

In addition, genomics and synthetic biology now permit the generation of microbial factories that produce large and cost-effective compounds used by the chemical industry as drug precursors. For example, production of semisynthetic artemisinin (an antimalarial compound) from artemisinic acid produced by microbial factories, is an early success story that combines metabolic engineering and synthetic biology [47]

Biotechnology is also enabling in development of vaccines against certain diseases, such as Human Papilloma Virus that is the cause of cervical cancer, and it enables improvement on vaccines for other diseases such as pneumonia and meningitis. Vaccines are indeed one of the most cost-effective public health tools to prevent infectious diseases.

4.7.1 The health bio-economy in the developing countries

Bio-similars are new follow-on biological medicines such as monoclonal antibodies, which involves exhibition of high level of similarity to a reference product already been authorized for use, as supported by appropriate analytic testing and clinical trials. The first-generation biotechnology based medicines are now off-patent and the bio-similars are significantly reducing the cost of these products[2].

In 2013, the first generic version of the infliximab monoclonalantibody against TNF-alpha was the world's first bio-similar monoclonal antibody to be approved by the European Medicines Agency. In principle, the cost of drug discovery is not being covered by generic manufacturers and thus generic medicines can be offered at a significantly lower price than the original drugs. However, there are critical issues in the production of biological drugs that set them apart from small molecule drugs, which can be produced as generics in a much simpler manner. Proteins not only need to assume proper structure for activity, they also often require post-translational modifications, are generated in complex biological systems (microbial or vertebrate cell lines), are intrinsically unstable and show remarkable micro-heterogeneity [48]. In addition, their production, purification and validation are complex processes that require adequate skills.

In recent times, large bio-pharma corporations are seeking a partnership with the local biopharmaceutical industry in emerging economies to perform manufacturing in these countries, with local contract manufacturing organisations (CMOs). This strategy is likely to facilitate the emergence of a bio-similar industry as well as drug development services in these countries [2].

Similar considerations also apply to the development of diagnostic kits for infectious and genetic diseases. These can certainly be produced locally by developing countries at costs that are significantly lower than those of imported products, with comparable sensitivity and specificity.

5. CONCLUSION

Biotechnology has a strong potential to contribute immensely to the eradication of extreme poverty & hunger, ensure food security, improve & provide affordable maternal healthcare, combat HIV/AIDs, malaria & other diseases, ensure environmental sustainability, create employment/jobs and develop a global partnership for development. This therefore implies that biotechnology occupy a very strategic position in the development of the nation (Nigeria) in particular and the world at large[49].

Biotechnology revolution has increased new industries focused on manipulating human, animal, plant and microbial agents to create heretofore unattainable products and services such as fermented food products which have great potential as key protein, fatty acid and good sources of gross energy, therefore, condiments are basic ingredients for food supplementation and their socio-economic importance cannot be over emphasized in many countries especially in Africa and Asia (India) where protein calorie malnutrition is a major problem. Its application in the health sector cannot be overemphasized too as it has helped in offering many therapeutic remedies to so many health disorders. Biological organisms that are being used in biotechnological processes are microorganisms, which are very small living things which are invisible to the naked eyes but can only be seen with the aid of a microscope. They play this vital role because of the genetic configuration, their short generation time, ease of manipulation, their use of synthetic medium for growth among other factors. Biotechnology occupies a very strategic position in the socio-economic advancement and development of the nation in particular and the world at large. Investments therefore should be made on more sustainable and renewable raw materials – a bio-based economy rather than the conventional or the traditional methods so as to provide a cleaner and healthier environment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. OECD. The Application of Biotechnology to Industrial Sustainability. OECD. 2001;2.
2. Lokko Y, Heijde M, Schebesta K, Scholtès P, Van Montagub M, Giacca M. Biotechnology and the bioeconomy. Towards inclusive and sustainable industrial development. New Biotechnol. 2017;986:1–6
3. Tietyen JL, McGough S, Kurzynske JS. Consumer perceptions of food-related health risks. Society for Nutrition Education Annual Meeting, Charleston. 2000;12–37.
4. Edema MO. Microbes and national development. First international conference on science and national development, college of natural sciences, University of Agriculture, Abeokuta. 2004;55.
5. Food and Agriculture Organization (FAO). Biotechnology applications in food processing: Can developing countries benefit? FAO Biotechnology Forum. 2004;1–5.
6. Pertry I, Sabbadini S, Goormachtig S, Lokko Y, Gheysen G, Burssens S, et al.. Biosafety capacity building: Experiences and challenges from a distance learning approach. New Biotechnol. 2014;31:64–8.
7. Brundtland GO. Our common future. World commission on environment and development 1987;1–8.
8. Henkel J. Products. Environmental report. 1995;1–56.
9. Lemaux PG, Cho MJ, Ha PG. Production of transgenic tall fescue and red fescue plant sby particle bombardment of matured seeds derived from highly regenerative tissues. Plant Cell Reports. 2000;19(11):1084–1089.
10. Bessin RT. Genetic Modified Organisms: A consumer perspective. NCB GMO Symposium. North Central Branch, Entomological Society of America Meeting, Minneapolis; 2000.

11. Zechendorf B. Sustainable development: how can biotechnology contribute? TIBTECH. 1999; 17:219–225.
12. Beard JL, Connor JR, Jones BC. Iron In Brain. Nutr. Rev.1993;5(6):157–170.
13. Mallick N, Rai LC. Removal of inorganic ions from wastewaters by immobilized microalgae. World Journal of Microbiology and Biotechnology. 1994;10(4):439–443.
14. Maheshwari DK, Gohade S, Paul J, Varma A. Paper mill sludge as a potential source for cellulase production by Trichodermareesei QM9123 and Aspergillusniger using mixed cultivation. Carbohydrate Polym.1994;23: 161–163.
15. Schaub SM, Leonard JJ. Composting: An alternative waste management option for food processing industries. Trends in Food Science & Technology. 1996;7(8):263–268.
16. Markert B. Plants as biomonitors: Indicators for heavy metals in the terrestrial environment. Phytochemical Analysis. 1993;6:644
17. Luton PE. Bioremediation-waste treatment applications for the pharmaceutical industry. Pharm Technol Eur.1997;9(5):19–24.
18. Gavrilescu M, Chisti Y. Biotechnology: A sustainable alternative for chemical industry. Biotechnology Advances. 2005;23:471–499.
19. Pletsch M, Santos de Araujo B, Charlwood BV. Novel biotechnological approaches in environmental remediation research. Biotechnol Adv.1999;17: 679–687.
20. Macek T, Martina M, Kas J. Exploitation of plants for the removal of organics in environmental remediation. Biotechnology Advances. 2000;18(1):23–34.
21. Gavrilescu M. Removal of heavy metals from the environment by biosorption. Life Sci Eng. 2004;4: 219–232.
22. Jordening HJ, Winter J. Environmental biotechnology: concepts and applications. Environmental Science and Pollution Research. 2004;12(2):124–124.
23. Khin T, Annachhatre AP. Novel microbial nitrogen removal processes. Biotechnol Adv. 200;22: 519–532.
24. Liu Y, Tay JH. State of the art of biogranulation technology for wastewater treatment. Biotechnol Adv. 2004;22:533–563.
25. Buyukgungor H, Gurel L. The role of biotechnology on the treatment of wastes. African Journal of Biotechnology. 2009;8(25):7253–7262.
26. Mohapatra PK, Mondal KC, Pati BR. Production of tannase by the immobilized cells of *Bacillus licheniformis* KBR6 in Ca-alginate beads. Journal of applied microbiology. 2006;102:1365–2672.
27. McCarty PL, Vogel TM, Cridle CSES&T. Critical reviews: Transformations of halogenated aliphatic compounds. Environmental Science and Technology. 1987;21(8):722–726.
28. OECD. Biotechnology and the changing role of government. Organization for Economic Cooperation and Development (OECD);1988.
29. Singh BD. Biotechnology. Text book on plant breeding. Kalyani Publishers, New Delhi, India. 1999;122.
30. Gupta PK. 2004. Pesticide exposure-Indian science. Toxicology. 2004;198(1-3):83–90.
31. Cunningham SD, Berti WR; Huang JW. Phytoremediation of contaminated soils. Trends in Biotechnology.1995;13:393–397.
32. Sigoillet JC, Mougin C, Sohier L. Des champignons pour réhabiliter les sols pollués. Biofutur. 1997;170: 34–36.
33. Swannell RPJ, Head IM. Bioremediation comes of age. Nature. 1994;368: 396–397.
34. Munnecke DM, Johnson LM, Talbot HW, Barik S. Microbial metabolism and enzymology of selected pesticides. In: Biodegradation and Detoxification of Environmental Pollutants, (ed AM Chakraborty). CRC Press, Boca Raton, FL. USA. 1982;1.
35. Pimentel D, Hart K. Public health and costs of pesticides. In: Pimentel, D., Ed., Encyclopaedia of pest management, Marcel Dekker, New York. 2002;677–679.
36. Agarwal SK. Advanced Environmental Biotechnology. Air pollution A. P. H. Publishing Corporation, New Delhi, India. 2005;200–328.
37. Hall FR, Menn JJ. Biopesticides: Use and delivery. Humana Press. Totowa, NJ. 1999;1–10.
38. Koul O, Dhaliwal GS. Advances in biopesticide research. Microbial biopesticides, Taylor and francis, UK. 2002;340.
39. Johnsson L, Hokeberg M, Gerhardson B. Performance of the Pseudomonas chlororaphis biocontrol agent MA 342 against cereal seed borne diseases in field

experiments. Eur J Plant Pathol. 1998;104:701–711.
40. Zechendorf B. Biopesticides as integrated pest management strategy in agriculture. In: Novel Approaches to Integrated Pest Management, (ed R Reuveni), Lewis Publishers Inc., Boca Raton, FL, USA. 1995;231–260.
41. Stone R. Researchers score victory over pesticides-and pests-in Asia. Science.1992;256: 1272–1273.
42. Kelly C, Knutzen E. The urban homestead: Your guide to selfsufficient living in the heart of the city. Port Townsend: Process Self Reliance Series, Francis. London. 2008;307.
43. Aalok A, Tripath AK, Soni P. Vermicomposting: A better option for organic solid waste management. Journal of Human Ecology. 2008;24:59–64.
44. Sarrouh B, Santos TM, Miyoshi A, Dias R, Azevedo V. Up-to-date insight onindustrial enzymes applications and global market. J Bioprocess Biotech. 2012;4:33–55.
45. Li S, Yang X, Yang S, Zhu M, Wang X. Technology prospecting on enzymes: Application, marketing and engineering. Comput Struct Biotechnol J. 2012;9017.
46. Kinch MS. An overview of FDA-approved biologics medicines. Drug Discovery today. 2015;20:393–8.
47. Paddon CJ, Keasling JD. Semi-synthetic artemisinin: A model for the use of synthetic biology in pharmaceutical development. Nat Rev Microbiol. 2014;12:355–67.
48. Kresse GB. Biosimilars-science, status, and strategic perspective. Eur J Pharm Biopharm. 2009;72:479–86.
49. Ezemba CC, Nwankwo A, Nwakoby N. Biotechnology an Engine of growth for National Development. Education and National Development; Issues and way foward. Book of Readings in Honour of Prof. S.E. Omebe, Provost *Ebonyi State College of Education*, Ikwo, Ebonyi State, Nigeria. Ebonyi State College of Education, Ikwo Printing Press Limited. 2018;(58):532-542.

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