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A Review of Agricultural Biotechnology: Potentials and Limitations in Africa

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ABSTRACT: Despite various successes in the development and application of biotechnology, over 800million people are still chronically undernourished and 180 million children are greatly underweight for their ages in Africa. Hence, agricultural biotechnology could be of great important in alleviating these problems, while the issues of food security, equity and sustainability would be achieved. Biotechnology is recognized as a technology that could assist in improving livelihood in Africa. This article discusses the potential and related opportunities and limitations of biotechnology in Africa.

Key Words: Agricultural Biotechnology; Feedstuffs; Breeding; Genetic manipulation; Ethnoveterinary.

Introduction

Africa Countries are faced with the shortage of food to feed the geometrically increasing population. More than 170million pre-school children are undernourished while more than half a million of children go blind each year from lack of vitamin A, million of women and children are exposed to iron deficiency which make them vulnerable to a host of diseases (1). Hence, biotechnology is regarded as a means to an end and not the end in itself. The science will assist in addressing the production constraints of small scale or resource poor farmers who constitute more than 70% of the food produced in Africa.

Biotechnology is a term, which was coined from two words thus: Biology and Technology. Biotechnology is an exciting field where biology either alone or in combination with other sciences creates promises felt in many ways (2). Biotechnology could also be related to the whole range of method both old and modern, which is used in manipulating organic substances so as to satisfy human needs. Biotechnology is an integrated use of biochemistry, microbiology and chemical engineering so as to achieve the technology application of the capacity of microbes and cultural tissue and cells.

The term ”Biotechnology” means different things to different people. The brewing of beer from barley or the fermentation of milk into milk products like yoghurt, cheese, as well as the use of ethnoveterinary vaccines in the treatment of various diseases and pest. A mother in the kitchen trying out a new way of making bread is as much a Biotechnologist as a scientist who is busy working at his laboratory on genetic engineering of a new potato plant.

Biotechnology is first becoming a vital tool for improving the quality of life in various ways, both now and in the future and these ranges from saving medicines to the availability of more nutritious foods.
Biotechnology has been with us from time immemorial but what is new in biotechnology include recombinant DNA technology and associated technique, monoclonal antibody techniques and embryo manipulation technology. All these have stimulated the manipulation of biological system for the benefit of human being. Hence, the thrust of this paper was to review available data and reports on agricultural biotechnology and to identify those, which have been used or may be used in Africa. Allied with the above points, the paper gives the broad benefits of biotechnology as well as the possible criticism given by critics. The paper concludes that Biotechnology will help in making agriculture to be sustained as the approach will contributes to the maintenance of quality of life for the present and future generations.

There are various areas of biotechnology but biotechnology in livestock nutrition, reproductive biotechnology, biotechnology of feedstuffs, microbial biotechnology, genetic manipulation, merit and demerits of agricultural biotechnology are discussed herein

Biotechnology in Livestock Nutrition

Biotechnology has a wide range of importance especially as far as boosting livestock productivity. For instance, crops improved through biotechnology provide nutritionally enhanced feed for farm animals; with the addition of amino acids and hormones to improve animal size, productivity and growth rates. Through biotechnology many of these feed can increase digestibility of low quality roughage. Also, scientists are now working on new crops to develop feed with edible vaccines for farm animals (3).

Biotechnology provides new tools for improving animal health and increasing livestock and poultry productivity. These improvement came from the enhance ability to detect, treat and prevent diseases and other problems, from better feed derived from transgenic crops designed to meet the dietary needs of various farm animals; and from improved animal breeding.

Biotechnology allows farmers to quickly diagnose livestock diseases such as brucellosis, foot and mouth disease (etc) through DNA and antibody based tests. Biological vaccines are also discovered to protect farm animals from a wider range of diseases like scours, brucellosis, shipping fever, fowl cholera, Newcastle disease of poultry.

Biotechnology can be applied to produce biotech cows, pigs and lamb with reduced fat and increased lean muscle. Biotech cows can produce designer milk with increase level of protein that can improve the diet of children or affect production of cheese and yoghurt.

Biotechnology In Ruminant Nutrition

The dominant feature of ruminant digestive tract especially cattle is the rumen. Current methods for manipulating ruminal fermentation that involve microbial biotechnology include dietary ionophores, antibiotics and microbial feed additives. The advent of recombinant DNA technology indicates that, future methods will have a much wider scope. It was suggested that ruminant fermentation can be improved in future through genetically engineered ruminal microorganisms. Wallace (4) suggested certain terminal objectives to be met before such genetic manipulation can be made possible. Firstly, methods of inserting foreign or modified genes into ruminal microorganisms and ensuring their efficient expression must be developed. For instance, broad host range plasmids and transposons were developed successfully to introduce new DNA into ruminal bacteria. Presently, only antibiotics resistance markers have been transferred while there is also wide possibility of introducing other genes into selected ruminal bacteria.

Secondly, the expression of the gene products should be known to be nutritionally useful in vivo. This includes polysaccharides for improving fiber digestion, methods for improving the amino acid composition of ruminal bacteria and breakdown of plant toxins

The third objective is that mechanisms have to be found for introducing and maintaining the new strain in the mixed ruminal population (4). It is then noticed that the use of non-ruminal organisms such as sachromyces cerevisae rather than indigenous ruminal species is preferable as a vehicle for implementing the benefits of recombinant DNA technology to ruminal fermentation. The use of yeast as feed additives is already generally accepted. Addition of particular enzymes to the diet is also useful for implementing the benefit of recombinant DNA technology to ruminal fermentation.

Potential areas of biotechnology in ruminant nutrition.

Improving the nutritional value of rumen synthesized protein

The microbes in the rumen, ferment feed materials to produce mainly short chain organic acids or volatile fatty acids, methane and carbon dioxide and the process provides substrate (feed) and ATP (energy) for the growth of microorganisms. Coleman (5) reported that protozoa are now recognized as having an overall negative effect in the rumen, particularly where ruminants are fed forage diets low in true protein. Protozoa ingest and digest bacteria and reduced the bacteria biomass in the rumen (5) and consequently the protein supply to the animal. Thus, they decrease the protein to energy ratio in the nutrient absorbed and at the same time increase the requirement of animal for true protein.

It was reported that using rumen-protected amino acids in supplementing ruminant diets is a wise step towards achieving more protein through the rumen. Rumen protected amino acids is a new amino acid supplements that contains regular amino acid or other analog with a unique ability to pass through the rumen intact. This can be used as an alternative to bypass protein products known as undegradable intake protein used by many dairy producers

Bacteriocins As Ionophore Alternatives

Bacterial are the principal organisms that digest plant cellulose and other feed materials consumed by the ruminant animals Bacteriocins are antimicrobial proteins produced by bacteria. The production of bacteriocin couple with resistance from bacteriocins produced by other bacteria allow a bacterial strain to colonise an environment and exclude competing bacteria.

Ionophores are used as feed additives in cattle production to improve efficiency in milk quality (fat) composition and reduce methane production

Targeting Rumen Protozoa

Substrates are transformed into their end products with the combination of protozoa and bacteria. Hence there is an interrelationship between the two. Coleman (5) reported that the number of bacteria engulfed by protozoa depends on the proportion in which they were present in the medium. However, some scientists reported an increasing dry matter digestibility (18%) when protozoa had been removed from the rumen hence scientist are working on how to limit rumen protozoa without affecting rumen bacteria with the use of compounds like saponin-containing plants, ionophores fatty acids and surfactants, which would increase the efficiency of protein in cattle. Vegetable oils are also being tested to limit protozoa and to increase the content of desirable conjugated linoleic acid in meat.

Reducing Phosphorus Pollution

A gene was cloned from a particularly vigorous rumen bacterium that is capable of releasing the phosphorous in feed that previously unavailable to the animal. The gene has been cloned into expression systems that are capable of producing large amounts of the enzymes for evaluation in poultry feeding experiments.

The developments of new feed enzymes have resulted in the improvement of feed utilization in cattle diets. It involves the addition of microbes *(Trichoderma spp, Aspergillum niger, Oyster muchroom, Vorvarilla volvaceae e.t.c.)* or enzymes to breakdown fibre in forage and grains in ruminant diets (6,7). The results are that ruminant animals can extract more nutrients from their diets, thereby achieving greater

efficiency which significantly enhances production performances. The use of yeast in the diet of ruminant animals is well documented (8). This method has a way of delivering biologically active proteins (enzymes) and growth factors to the small intestine of ruminant animals.

Biotechnology In Monogastric Nutrition

Monogastric animals are known for their inability to effectively digest fibrous feeds. Although, pigs are able to digest 30% of fibrous feed due probably to caecal fermentation. Biotechnology is a major tool that is capable of improving monogastric nutrition. The use of oil seed protein residues such as palm oil studge are generally limited by the fibrous components and in some cases the presence of secondary plant compounds which may be toxic or simply lower production. The fibrous content can be reduced by pre-treatment of the materials using fungi (white rot species rot). The process will enhance the protein content through the addition of fungal protein (9).

Modification of digestive function through the development of transgenic animals.

The process of encoding gene for microbial cellulase or hemicellulase into animal genome is a kind of genetic engineering capable of modifying digestive function of monogastirc for better digestibility. While porcine growth hormone can also be injected into animals on grain based concentrate so as to improve growth efficiency.

Biotechnology of feedstuffs.

Nutritionists are always faced with the problem of antinutritional factors during feed formulation. Such antinutritional factors like trypsin, inhibitors, saponins tannins, phytates, oxalates, high fibre, phosphorus content are problems in feeding stuffs etc. The problems could be solved by the development of genetically modified grain, which is having improved nutritional values.

Low Phytate and High Oil Corn

All plant feed ingredient have natural phosphorous which is only 30% available while the remaining 70% are not available. Hence, if grains with high available phosphorus were made available, the use of supplemental inorganic phosphorous like dicalcium phosphate in poultry diet will be minimized. This would not only reduce the cost but also a high quality bioavailability phosphorous will be available to the poultry birds. The added advantages is that less phosphorous will be found in the litter and manure of livestock which would result in the control of entrophication.

Studies on feeding with high oil corn on broiler performance showed that there was a significant improvement in body weight and feed conversion. Council for Biotechnology Information (10) reported that broilers fed on high oil corn has less abdominal fat, compared to broiler fed on conventional corn, also hens fed on high oil corn diet showed better production (quality and quantity) and when the yoke was analyzed, it was found to contain increasing levels of linoleic and oleic acids.

Livestock Breeding and Health

Classical livestock breeding which has been successful was found to be a slow process which took many years before it could be achieved. However, with the introduction of biotechnology, it was easier to produce animals with superior genetically character and to multiply these livestock rapidly. It is note worthy that biotechnology has large potentials for genetic improvement in livestock hence, reproductive biotechnology is an uncontested tool for a better breeding efficiency and it application can provide achievements in the following areas:

- Improvement of genetic traits by integrated breeding programs based on biotechnological method (AI, MOET, cloning, IVF)
- Utilization of specific traits by Transgenesis
- Genome analysis for breeding value determination

- International exchange of genetic materials
- Efficient eradication of defective genes and diseases (11).

With the DNA testing of blood sample, some genetic defect can be identified in animal before such animal is use for breeding purposes.

A number of DNA test are now available to detect inherited weakness of cattle and conditions identified by the test include leukocyte Adhesion Deficiency and this causes repeatedly bacterial infections, stunted growth and death within one year of life.

Additionally a new DNA test was developed to identify the gene associated with porcine stress syndrome any pig carry the gene can now be excluded from the breeding programme. Porcine Stress Syndrome (PSS) symptoms include muscle tremors, difficulty breathing, reddish and blotched skin with high body temperature and finally the animal may collapse and die.

Several reproductive techniques available include artificial insemination (AI), embryo transfer and other associated technologies thus: evaluation of progesterone in milk or blood which is used in monitoring ovarian function. The utilization of artificial inseminations to produce a multiple embryo and the subsequent transplanting of the embryo to unrelated female for gestation was achieved through biotechnology. Other advances in biotechnology in livestock production include the production of clones (genetically identical progeny) improved freezing techniques for semen oocytes and embryos and the genetic evolution of sperm used in artificial insemination. The use of hormone injection (superovuIation) for the production of more eggs in female was also achieved through biotechnology. With the help of biotechnology the best female animals are being used as a source of genetic materials rather than a direct source of offspring i.e. they have a higher reproductive rate than would otherwise be possible.

Low Oligosaccharides Soybean

Soybeans contain raffinose and stanchyose, the oligosacchrides act as antinutritional factors. Oligosaccharides are known to cause osmotic carthisis in laboratory animals. However, there are newly developed genetically modified soy low oligosaccharides. Council for Biotechnology Information (10) revealed that the new varieties of soy beans gave an increase of 30% in amino acids digestibility. Soybeans with high lysine are also being developed so as to increase the lysine content from 3-4.5%. This would help in reducing the supplemental addition of lysine in diets.

Microbial Biotechnology

The totality of genetic materials in the DNA of a particular organism is known as “genome”. Genomes differ greatly in size and sequence across different organisms. Knowing the complete genome sequence of a microbe provides vital information about its biology and this helps to understand the microbe’s biological capabilities and their modification especially for agricultural purposes.

Microbial biotechnology has to do with genome manipulation of the microbes. Historically, human beings have exploited some of this microbial diversity in various ways thus, the production of fermented foods like cheese, yoghurt and bread. Additionally, some soil microbes like azotobacter, nitrobacter, nitrosomonas help in releasing nitrogen needed by plant for proper growth. Microbial biotechnology and microbial genomics research is vital for advances in food safety, food security, value added product, human nutrition and functional foods.

Microbial biotechnology can be applicable in agriculture for fibre degradation, and bioremedation of soil contaminated with pesticides (hexachloro cyclohexane, paranitrophenol). Defibrization of fibrous waste agricultural residues are well documented in literature(12 ,3,14).

Genetic Manipulation

It involves transfer of gene (s) from one organism to another through recombinant DNA techniques resulting in the production of transgenic organism. Successful production of transgenic livestock has been reported for pigs, sheep, rabbits and cattle (15) genetic modification offers considerable opportunity for

advances in agriculture and medicine. In livestock, it helps in the breeding of commercially superior stock with higher desirable traits (resistance to diseases and pest and tolerance to environmental stress).

Ethnoveterinary Medicine

The indigenous knowledge and practice of animal health was based on the traditional ways of treatment of various diseases by the local farmers using various medicinal plants. Various ailments treated with medicinal plants are well documented thus skin diseases, respiratory infection diarrhoea, fever, eye infection, wounds, internal and external parasites. The most common parts of medicinal plants used are seeds, leaves, barks, tubers, roots, herbs and plant extract.

There are some limitations to the use of ethnoveterinary medicine which incude, collection, sorting, cleaning and preparation. Additionally, standardizing the local vaccines and drugs and the determination of the optimum dosages and treatment schedules are difficult (16, 17)

Despite the aforementioned, ethno veterinary medicine still has great potential, which include the following:

(a) Cheaper and available veterinary options are available to be chosen from and greater improvements in animal health can be realized.

(b) The income generation will be appreciable due to reduce need to purchase animal products.

(c) There will be increased food security due to improved condition and hence livestock value

(d) There will be decrease risks to the environment, livestock and human health.

Risks Of Biotechnological Products

Opponents of biotechnology have raised some legitimate concerns (18) about the genetically modified organisms (GMO). Among the shortfalls of GMO products are:

i. That nobody knows whether the GMO products brought to African meet certain safety and quality standards prior to commercialization and importation.

ii. There is no open and accessible regulatory process in place to assist the public in understanding the risky and benefit associated with transgenic Products in Africa.

iii. The delineation of lead and supporting agency jurisdiction over transgenic Products are generally not defined in Africa.

iv. There is no agency charged with the regulation of transgenic animal and plant products consumers in African do not know what is in their food (GMO products).

v. Dangerous organism could be unleashed unintentionally to the environment.

However, advancement made by biotechnology can significantly improve the quality of life in various areas. These benefits most be pursued with the most responsible available science.

Benefits of Biotechnology

- Agricultural biotechnology can be used to help farmers in developing countries to produce more by developing new crop varieties which are drought- tolerant; resistance to diseases, pest and weeds and also be able to fix nitrogen from the atmosphere.
- Agricultural biotechnology can also make the food farmers to produce more nutrition food by enhancing the vitamin A, iron and other nutrients in the edible part of the plant.
- Through agricultural biotechnology, a beta-carotene and iron enriched “golden” rice was developed. This may help give young children in Africa countries the vitamin needed by their body as well as sufficient iron to help prevent iron-deficiency anaemia

- Biotechnology provides significant environmental benefits by reducing the use of crop protection chemicals, as plants have the ability to protect themselves e.g. corn, potato and cotton-produce a protein that helps in the control of larvae of certain harmful insects feeding on the plant
- Biotechnology provides opportunities to decrease soil erosion and green house gas emission through farming practices that protect the environment
- Biotechnology helps provide food crops with higher level of nutrients that may help reduce the risk of heart disease and certain cancers.
- Biotechnology provide soy bean oil with reduced saturated fat
- Biotechnology will arm important crops such a sweet potato, cassava, papaya, rice and corn with defenses against viruses.
- Biotechnology will help increase, crop ability against inclement weather conditions (drought, soil toxicity and floods).
- Biotechnology helps in reducing the period it takes for plant breeders to develop the plant farmers need to row better crops.

Conclusion

Increasing food production in Africa should be the collective responsibility of everybody. Africa countries should be assisted to participate more effectively and equitably in international commodities and food trade while, international organization should provide technical information and assistance as well as socio-economic and environmental analyses on major global issues related to new technological development.

Additionally, government in Africa counties must invest in biotechnology research so as to help poor farmers, while the public and private sectors must work as partners. The potential of the new agricultural biotechnology is enormous, particularly for the poor in developing countries. A better awareness of agricultural biotechnology products and the vital role they play in fulfilling and meeting the challenge of the 21st century is vital in providing more food or nutritious food in a way that the environment is not threatened.

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