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Review Article

PROGRESS OF FOOD PRODUCTION AND FOOD PROCESSING BIOTECHNOLOGY IN AFRICA: A SYSTEMATIC REVIEW

MELAKU TAFESE AWULACHEW*

Food Science and Nutrition Research, Ethiopian Institute of Agricultural Research, Ethiopia. Email: melakutafese12@gmail.com

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ABSTRACT

The increase in human population worldwide has become a major threat to food security and nutrition. Food production and processing sector particularly the agriculture and food processing are asked to satisfy two apparently contradictory needs, to become more productive, and at the same time, more sustainable. Biotechnology is one of the sectors with significant contribution in modernizing agriculture, food security, and nutrition. Africa including Ethiopia has started research in agricultural-food processing biotechnology a few decades ago. However, research and public awareness on biotechnology is inadequate. This review appraises the agriculture/food production and food processing biotechnology progress in developing societies particularly in Africa so as to understand the roles which agricultural and food processing biotechnology could play therein. The paper concludes with the recommendation that individual countries need to identify their specific national priorities and preferences in food production and harness the growing body of science and innovations in genetic engineering and food processing to address specific issues.

Keywords: Biotechnology, Food production, Food processing, Constraints, Trend and status

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INTRODUCTION

Global population growth has become a huge concern to food security and nutrition. Population growth, particularly in developing nations, would necessitate a 70% increase in food production by 2050 (Delaney, 2015), making considerable improvements in agricultural productivity over the next several decades a priority. Agriculture is being challenged to meet two seemingly contradictory needs: to become more productive while also becoming more sustainable, that is, to deliver needed food without depleting renewable resources.

Agriculture is completely dependent on the human race, and as world populations continue to grow, agricultural practices must be constantly reassessed to maximize their effectiveness. In this regard, biotechnology efforts have been focused on developing technologies that can boost crop yields.

Biotechnology is any technique that involves the use of biological creatures or their components, systems, or processes to manufacture or change products, improve plants or animals, or develop microorganisms for specific use (Edema, 2004). Biotechnology as a discipline attempts to develop new goods and processes that incorporate the most recent concepts and methodologies from modern biology. It combines biochemistry, genetics, and microbiology ideas and methods. Recent advances in molecular biology, genetic engineering, and cell chemistry have transformed biotechnology into a science that has resulted in advancements in protein chemistry, nucleic acid biochemistry, fermentation, and immunology (Graham, 1994). These advances are currently being sculpted to have a greater impact in agriculture, aquaculture, animal productivity, health care, and, most crucially, food processing.

Processing helps to ensure food security by reducing waste and losses in the food supply chain and boosting food availability and marketability. Food is also processed to enhance its quality and safety. Food safety is a scientific discipline that ensures that food will not harm the customer when prepared and/or consumed in accordance with its intended purpose (Maryam *et al*., 2017).

Strategy (EDSE, 1994) stressed the need to improve the agricultural sector. The two core industries highlighted as crucial for rapid economic change in this national development strategy are information and communication technology and biotechnology (FDRE, 2002). Traditional techniques dominate the agricultural sector, resulting in a failure to meet the food security needs of an ever-increasing population. Classical agricultural research has historically improved the country's agricultural productivity and, when appropriately supplemented with biotechnology, accelerates many processes and provides the finest alternative answers to agricultural difficulties. Agricultural biotechnology is more precise and cost-effective, with proven practical applications in tackling a wide range of agricultural challenges around the world. Knowing the numerous advantages of biotechnology, the United Nations strongly urged it for underdeveloped countries.

A fundamental public concern that has emerged in the implementation of biotechnology is what role agricultural/food production and food processing biotechnology can play in ensuring appropriate food and nutrition security in African countries in this millennium, and what are the primary problems confronting African biotechnology experts? This paper specifically aims to accomplish the following goals: Review/examine the roles that agricultural and food processing biotechnology could play in ensuring adequate food and nutritional security in developing societies and indicate the potential of agricultural and food processing biotechnology in modernizing the agricultural and food processing sector for developing societies, such as ethiopia.

AGRICULTURAL BIOTECHNOLOGY AND ADEQUATE FOOD SECURITY

To ensure food security in developing nations for the next three decades, a range of political, social, economic, and technical concerns must be addressed. The first stage in determining the use of new agricultural technology is to identify the challenges that have proven intractable using traditional methodologies. This intractable problem, among others, is food scarcity, which biotechnology now has the potential to solve. Recombinant genetics and biotechnology research tries to generate plant types that provide consistently high yields at the same

or lower cost by breeding in traits such as disease, insect, and stress tolerance. Realizing these objectives could result in massive increases in food production.

Because of their potential to directly modify plants, animals, and agricultural processes in response to new needs, biotechnologies play a critical role in agriculture. Biotechnology should be viewed as a means of developing a greater understanding of crop plants and animals through the collaboration of scientists from other fields, not just as a means of solving issues when traditional tactics have failed.

The International Institute of Tropical Agriculture and the Technical Centre for Agricultural and Rural Cooperation (1992) observed, however, that the growing importance of agricultural biotechnology, at least in plant improvement, should not obscure the fact that traditional plant breeding, based on hybridization followed by selection and evaluation of a large population in the field, accounts for more than 50% of the global increase in agricultural productivity (Nicholas and Igbokwe, 2007).

There is also a growing international agreement of scientific and regulatory opinion that crops developed from biotechnology are safe to use as food and feed and are environmentally friendly (Bruce, 2003). These and other promising technologies are now being applied to increase the production and yield of African staple crops such as cassava, yam, maize, millet, rice, soybean, sweet potato, sorghum, banana, oil crops, peanuts, and wheat. Protein-enhanced sweet potatoes and carotene-enhanced rice and oilseeds promise to boost dietary nutritional value.

BIOTECHNOLOGY IN FOOD PROCESSING

Food processing uses numerous unit procedures and technologies to turn relatively heavy, perishable, and often inedible raw materials into more usable shelf-stable and appetizing foods or drinkable liquids. Using various unit operations and technologies, palatable foods and drinkable beverages can be created by transforming a relatively large volume of perishable and non-edible food ingredients into more usable and shelf-stable products (Gargi, 2018). Biotechnology in the food processing business uses microorganisms to preserve food and produce a variety of value-added products such as enzymes, flavor compounds, vitamins, microbial cultures, and food components.

Microorganisms or microbes are broad words for a class of microscopic living organisms that include bacteria, yeasts, and molds (Edema, 2004). In the food processing business, biotechnology focuses on the selection and modification of microorganisms with the goal of enhancing process control, yields, and efficiency, as well as the quality, safety, and consistency of bioprocessed products while boosting process efficiency (FAO, 2010). Research is already underway to develop cassava varieties that can efficiently absorb trace metals and micronutrients from the soil, have improved starch quality, and contain more beta-carotene and other beneficial vitamins and minerals, as well as fruits and vegetables that could 1 day deliver life-saving vaccines, such as a banana that could soon provide the hepatitis B vaccine (Prakash, 2011). Mexican scientist Luis Herrera Estrella demonstrated that tropical biotechnology may be used to modify crops to survive aluminum and acidic soils, considerably increasing corn, rice, and papaya productivity (Prakash, 2011).

TRENDS OF BIOTECHNOLOGY IN AFRICA

Most African countries do significant biotechnology-related research, but only a handful have progressed to the stage of developing local and regional market products. Biotechnology development in African countries is based on established biotechnological centers, either regional or international in nature, that specialize *in vitro* cultivation of cash crops such as banana, coffee, cocoa, palm oil, and vanilla, as well as food crops such as maize, millet, cassava, and cowpea (Massola, 1992).

Other parts of agricultural biotechnology, such as plant tissue culture, marker-assisted selections, genetic diversity research, and non-target mutagenesis in plants, have been underway in ethiopia for quite some time. Assisted reproductive biotechnology in cattle began approximately five decades ago, with procedures such as multiple ovulation and embryo transfer, artificial insemination, vaccine research, and molecular approach-based disease diagnosis techniques. Characterization of biofertilizers (mostly rhizobia), as well as microbial and enzyme characterization, began many years ago in universities and EIAR as part of the microbial biotechnology research program. However, the majority of these efforts, as well as ongoing Ethiopian government assistance for human resource and molecular laboratory capacity building, were not properly documented.

Godliving (2011), on the other hand, assessed the condition of biotechnology policy frameworks in various Eastern and Central African nations such as Kenya, Uganda, Tanzania, Burundi, Ethiopia, Rwanda, and the Democratic Republic of the Congo (DRC). He noted that Ethiopia, Rwanda, and the DRC had no biotechnology policy framework, whereas Kenya, Uganda, and Tanzania had established a biotechnology policy framework (in 2007, 2008, and 2009, respectively) and Burundi (in preparation). In this regard, just 16 of the African Union's, 53 member countries have laws, regulations, guidelines, or policies governing modern biotechnology. Only South Africa, Egypt, and Burkina Faso have experience with GMO crop commercialization (Makinde *et al*., 2009).

The main issues confronting African biotechnology experts are a lack of resources, the sluggish transition of GM crops from experimental to commercial phases, and challenges in meeting regulatory criteria (Nyira, 1995; Thompson, 2004; Godliving, 2011). If Africa accepts biotechnology, it will significantly reverse its underdevelopment in terms of insufficient good quality food, poor health care, unreliable energy sources, and degraded habitats.

PROSPECTS OF AGRICULTURAL BIOTECHNOLOGY IN ETHIOPIA

Agricultural biotechnology products have been employed in numerous ways throughout Africa, either intentionally or unintentionally. Some countries have adopted GM crops, and it is difficult to imagine agriculture improving without current technologies. Biotechnology is used extensively in all agricultural areas (crop, livestock, and microbiological). Technology is not in its infancy; it is advancing quickly and plays an important role in agriculture (NASEM, 2021). The world's sudden population growth, notably in Sub-Saharan Africa (SSA), as well as unpredictable climate fluctuations and crop production pressures, necessitates the required application of agricultural biotechnology.

In crop variety development, current technology is more exact, saves time, and is less expensive. The main difficulty in SSA is the lack of technological capacity and the significant initial expenditure required to develop molecular research facilities (Daba, 2022). This is a must, and most countries are focusing and working hard on it. The previous sections' discussion of crop improvement, animal production, and the exploitation of microbial resources, as well as Ethiopia's favorable research policy, are currently encouraging the growth of agricultural biotechnology.

Many molecular research projects were underway, with notable successes, primarily in agricultural and livestock research. At present, public understanding of the technology is low, and there are issues in several areas of biotechnology, particularly GMOs. This scenario, however, will be reversed with increased biosafety regulatory capacity and more public awareness. This may be seen in the global adoption of biotechnology, which goes hand in hand with technical advancement.

ADVANCES IN SPECIFIC AREAS OF FOOD PROCESSING FOR DEVELOPING COUNTRIES

Improved food ingredients

Processing is typically used to make necessary changes to major food elements such as starches and oils. Biotechnology allows crop plants to be modified to generate only the parts that are required.

Starches

Plant breeders have inserted a bacterial gene into potato plants, increasing the amount of starch in tubers while decreasing their water content (FAO, 2010). This implies that the potatoes absorb less fat during the frying process, resulting in low-fat chips. Sweeter potatoes with higher sugar content than typical types have also been developed.

Oils

Rapeseed and sunflower oils are being modified to generate more stable and nutritious oils with linoleic acid rather than linolenic acid and lower saturated fat content (Peterson, 2000). Rapeseed has also been manipulated to generate a low-saturated-fat high-temperature frying oil (Codex Alimentarius Commission, 2009; Bessin, 2000; Betsch, 1998).

Dairy improvement

The dairy product business is another food processing sector that can gain economically from higher quality raw materials. Biotechnology has now been utilized by New Zealand scientists to raise the amount of the protein casein, which is important for cheese production, in milk by 13% (Betsch, 1998).

Product quality

Changes in the composition of raw material inputs can be made to benefit consumers (Okonko, 2006; Codex Alimentarius Commission, 2009). Researchers in biotechnology are extending the shelf life of fresh fruits and vegetables, improving the crispness of carrots, peppers, and celery, developing seedless grapes and melons, extending the seasonal geographic availability of tomatoes, strawberries, and raspberries, improving the flavor of tomatoes, lettuce, peppers, peas, and potatoes, and developing caffeine-free coffee and tea (FAO, 2010).

Advances in processing aids and additives

Food additives are substances provided by nature and are usually of plant or microbial origin, such as xanthan gum and guar gum, which are created by bacteria (Okonko, 2006). Probiotics are now manufactured in India for usage as food additives, dietary supplements, and animal feed (FAO, 2010). Biotechnology is being utilized by scientists to modify the starch in crop plants such that it no longer requires specific processing before use (BREI, 2006).

Enhanced raw materials food safety

Safety of the raw materials

Microbial contamination, which can occur at any step from farm to table, is the most serious food-safety risk that food producers confront. Microbial contamination is lower in transgenic disease-resistant and insect-resistant crops (Codex Alimentarius Commission, 2009; Bessin, 2000). New technological diagnostics detect microbial infections earlier and more accurately, allowing farmers to identify and remove infected plants and animals before they infect others. Nham, Thai fermented pork meat, depicts how consumer demand for safe food led to the commercial adoption of defined starter cultures, with government involvement and assistance (FAO, 2010).

Enhanced food safety

Biotechnology has improved the detection of bacteria and the toxins they create, ultimately enhancing food safety. Monoclonal antibody tests, biosensors, polymerase chain reaction approaches, and DNA probes are being developed and will be used to detect the presence of hazardous bacteria such as Listeria and Clostridium botulinum, which cause food poisoning and spoilage (BREI, 2006). Packaged fermented items, such as kimchi, miso, and tempeh, are commonly accessible in Asian stores (FAO, 2010). Traditional beers in Zambia are now manufactured in powdered and ready-to-drink containers, highlighting a very good example of product change that has occurred in response to consumer demand for safety convenience, both in domestic and international markets (FAO, 2010).

Fermentation

Traditional biotechnology has played an important part in the production of fermented foods, in which favorable modifications are created by the activity of microorganisms or enzymes, of which there are over 3,500 different types worldwide. African fermented condiments necessitate food processing technology that fulfills human needs/challenges.

Improving food fermenters

The importance of food fermentation on cultures has led to scientists doing several studies to improve the microorganisms that carry out food fermentation (Okonko, 2006). Researchers have used recombinant technologies to make some strains of the bacteria and other important fermenters immune to viral infection (BREI, 2006). Many microbial fermenters are being outfitted with this self-defense mechanism via biotechnology to reduce microbial contamination of fermented foods (BREI, 2006). The case study on soy sauce production in Thailand indicates success in the use of starting culture technology and enhanced bioreactor technology (FAO, 2010).

Improved inoculants for fermentation

There is a need for more effective use of appropriate starting cultures as inoculants during the fermentation process. A variety of appropriate starter cultures, either granular or in the form of a pressed cake, are used as fermentation inoculants in Asian countries for the production of fermented fish sauces and fermented vegetables, as well as cereal or grain fermentations in African and Latin American countries (Graham, 1994). These traditional mold starters are commonly known as marcha or murcha in India, ragi in Indonesia, bubod in the Philippines, nuruk in Korea, koji in Japan, ragi in Malaysia, and Loog-pang in Thailand (FAO, 2010).

Traditional approaches in gene improvement

Traditional genetic improvement methods such as classical mutagenesis and conjugation have been the foundation of industrial starter culture development in bacteria (a starter culture is a culture used to start a food fermentation), whereas hybridization has been used in the improvement of yeast strains that are widely used industrially in baking and brewing applications (FAO, 2000; 2004). South African biotechnological developments are currently focusing on improving Saccharomyces cerevisiae strains to improve the wholesomeness and sensory quality of wines, changing preferences away from basic commodity wine (FAO, 2010).

CONSTRAINTS TO FLOURISHING OF BIOTECHNOLOGY APPLICATIONS IN AFRICA

Biotechnology advantages are still difficult to actualize due to varied degrees of limitations that have hampered the promotion of sustainable socioeconomic development in developing nations around the world (FAO, 2010). Shortages of competent labor, equipment, and facilities, as well as funding for recurring expenditures, inadequate policies and priorities, and technological know-how, continue to be major challenges for developing countries (Okonko, 2006). These areas require significant investment and development if any country is to reap the benefits of biotechnology. Investing in human resource development is critical to overcoming other barriers to biotechnology (FAO, 2010). This can be seen in the decline in the number of doctoral graduates and researchers who are unable to find the necessary physical and intellectual environment to promote professional development and acquire the necessary scientific experience, resulting in a shortage of well-trained and experienced scientists (Graham, 1994).

The high expenses of biotechnology research, a lack of venture capital or public financing to assist the creation of necessary infrastructure, and the running costs of the research itself in poor nations are all important constraints (Graham, 1994). With the lower per capita purchasing power of potential users of new products in most developing countries compared to the availability of very lucrative markets in developed

countries, companies involved in biotechnology research find it less appealing to establish research facilities or subcontract research in developing countries (Graham, 1994). Most developing countries lack the appropriate legislative framework, as well as the associated laws and regulations, to promote biotechnology research and development, which hinders technology transfer and economic connections (Graham, 1994).

OPPORTUNITIES AND OPTIONS OF BIOTECHNOLOGY FOR DEVELOPING COUNTRIES

Opportunities of agricultural biotechnology

In the country, there are numerous potential for agricultural biotechnology research and development. This is attributable to the international and national trend of bioscience research and development. Many renowned companies in the medical, pharmaceutical, cosmetic, food, and feed industries are currently exploiting this technology for a variety of purposes. Aside from biological uses, analytical solutions for research in this domain generate enormous resources for developed countries. The cost of the most recent DNA sequencing machine is currently comparable to the annual export value of several agricultural commodities from developing nations.

Agricultural biotechnology has made important contributions and applications in all biological research fields. As a result, the Ethiopian government has prioritized human resource and physical capacity development. At present, the National Agricultural Biotechnology Research Center in Holetta has practically all of the necessary infrastructure and people resources (Daba, 2022). The foundation of the Ethiopian Institute of Biotechnology (EBTi/BETin) in 2016 is one of the testimonies to the government's dedication to and knowledge of the importance of biotechnology. This is a significant step forward in centrally managing all biotechnology sectors in the country.

Furthermore, more than 13 public institutions provide post-graduate biotechnology courses (Daba, 2022). Other large institutes that use biotechnology include the National Veterinary Institute, the country's pioneer in biotech, and the National Animal Health Diagnostic and Investigation Center. All of these national institutes represent significant opportunities for research in the country. The Ethiopian Society of Biotechnology was founded in 2020 to bring together all biotech stakeholders and annually examine and analyze the sector's progress.

Identifying options of food processing biotechnology for developing countries

It is vital that countries recognize the potential of fermented foods and prioritize actions to ensure their safety, quality, and availability. Based on the stocktaking exercise in this document, several specific options can be identified for developing countries to help them make informed decisions regarding the adoption of biotechnologies in food processing and in food safety for the future **(**Singh, 1991**).** The development of a critical mass of motivated scientists is a crucial element to all developing countries. More resources from the development assistance agencies should be devoted not only to the training of these scientists but also to the building of appropriate physical environments where they can execute their research works **(**Gaston, 1994**).**

Countries must acknowledge the promise of fermented foods and prioritize steps to ensure their safety, quality, and accessibility. Based on the stocktaking exercise in this publication, some particular choices for developing nations can be identified to assist them in making informed judgments about the future use of biotechnologies in food processing and food safety (Singh, 1991). Emerging a critical mass of motivated scientists is vital for all emerging countries. More resources from development agencies should be dedicated not only to the training of these scientists but also to the construction of proper physical facilities in which they may carry out their research (Gaston, 1994).

Table 1: Plant-based biotechnology has so far achieved in South, West, and North Africa countries (Godliving, 2011)

Country	So far achieved
South Africa	Already developed and commercialized transgenic products such as maize and cotton
Other South African countries: Zimbabwe, Malawi and Madagascar	Are doing micro-propagation of disease-free banana, rice, maize, groundnuts, and tropical woody trees.
North African countries: Morocco and Tunisia	Are doing biological research and preliminary trials on palms, potatoes, tomatoes, maize, and forest trees
West African countries: Burkina Faso, Cameroon, Cote d'Ivoire, Ghana, Nigeria, Gabon & Senegal	Are doing various projects related to biological nitrogen fixation; production of legume inoculants; fermented foods; medicinal plants; plant tissue culture of cocoa trees, rubber trees, coffee trees, yams, oil-palm, pineapple, cotton, tea, banana, cassava, ginger, eucalyptus and acacia; and production of mycorrhizal-based biofertilizers for rural markets

Because training is currently almost entirely available abroad, and developing nations are experiencing economic hardship, and the only realistic access to this technology is one supported by donors (Chetsanga, 1994). One would want to encourage the international community to launch special scholarships to enable trainees to acquire.

Premises of biotechnology in Ethiopia

Ethiopian biotechnology research and development is in its infancy in comparison to neighboring countries such as Kenya and Uganda, where modern biotechnology ventures are taking root (Thomson, 2008; Godliving, 2011). The lack of a biosafety policy and guidelines; the lack of a proper assessment of the level of biotechnological capacity available in the country; poor coordination of the limited biotechnological capacity available in some institutions and research centers; the public's lack of appreciation for the opportunities provided by agro-biotechnology; and financial constraints suggest that the government must act quickly to address the situation (Abraham, 2009).

Agriculture accounts for 41% of Ethiopia's economic activities, including marketing, processing, and export of agricultural products. Coffee, beans, oilseeds, cereals, potatoes, sugarcane, and vegetables are among the most important crops (Kassa, 2011). Ethiopia currently lacks a national biosafety policy (Godliving, 2011). It needs one to build capacity and utilize technologies in agriculture, the environment, health, and energy.

Ethiopia's agriculture industry is centered on traditional or conventional subsistence agriculture, which is vulnerable to biotic and abiotic variables. This is why, although being a global concern, the global climate effect is severe (FSIN, 2021) in underdeveloped countries. Ethiopian agricultural biotechnology research began decades ago with artificial insemination in livestock and plant tissue culture. The country's research and capacity-building operations have been gradually strengthened, and a full-fledged research center and institute have been built. Using agricultural biotechnology to feed an ever-increasing population with limited resources and alternate ways of life is an option. For example, the usage of genetically modified crops, which has been around for more than 20 years, is a contentious subject in Africa. Pests, moisture stress, weed management, and better nutritional benefits could all be addressed by this technique. Improving these characteristics are time-consuming and often unattainable using traditional methods.

There are more acceptable and precise agricultural technologies, such as genome editing in crops, livestock, and microorganisms that could

alleviate significant agricultural challenges while also improving crop natural attributes. This suggests that agricultural biotechnology will have a bright future in Ethiopian agriculture. Negative disputes over new technology may continue or possibly intensify in Africa for a variety of reasons, but it is vital to accept modern agricultural biotechnological uses. Otherwise, many developing nations, including Ethiopia, may fall short of meeting the zero hunger target by 2030.

Ethiopia is currently supportive of agricultural biotechnology without jeopardizing biosafety concerns, and this trend is expected to continue, with the country maximizing the use of cutting-edge new techniques that can practically contribute to the improvement of agricultural production and productivity, ultimately leading to the global goal of nutrition security by 2030.

SUMMARY

Traditional biotechnology operations such as tissue culture and breeding are done around the world, while current biotechnology activities are mostly field-tested in Kenya and Uganda. None of the countries analyzed have yet commercialized any genetically modified products, but Kenya and Uganda are on their way. Biotechnology has enormous potential for promoting socioeconomic development in the Eastern and Central African region by increasing productivity, improving resistance to biotic and abiotic stresses, reducing pesticide use, and improving nutritional quality, all of which contribute to food security and poverty alleviation.

The region's key hurdles in biotechnology research and development are a lack of skilled human resources, inadequate infrastructure and facilities, and a lack of political will on the part of some governments.

Given the challenges to biotechnology transfer, African countries will need to focus on utilizing their natural, scientific, and technological resources to define problems and seek answers that will benefit large segments of their populations. These circumstances assuage developing countries' anxieties that they will be unable to receive adequate technologies and support from developed countries. Condiments are fundamental ingredients for food supplementation as a result of the biotechnology revolution, which has spawned new industries focused on manipulating human, animal, plant, and microbial agents to create previously unattainable products and services such as fermented food products with great potential as essential protein, fatty acid, and good sources of gross energy.

Biotechnology has the potential to benefit the region if governments invest more in terms of policy and resources to advance biotechnology development and commercialization. In the near future, biotechnology is predicted to play an important role in food security, improved health, and environmental management in the region.

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CONFLICT OF INTEREST

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