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Agricultural biotechnologies in developing countries: Options and opportunities in crops, forestry, livestock, fisheries and agro-industry to face the challenges of food insecurity and climate change (ABDC-10)

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Synthesis: Current status and options for biotechnologies in food processing and in food safety in developing countries

Introduction

Food processing makes use of various unit operations and technologies to convert relatively bulky, perishable and typically inedible raw materials into more useful, shelf-stable and palatable foods or potable beverages. Processing contributes to food security by minimizing waste and loss in the food chain and by increasing food availability and marketability. Food is also processed to improve its quality and safety. Food safety is a scientific discipline that describes the handling, preparation and storage of food in ways that prevent food-borne diseases.

Biotechnology as applied to food processing makes use of microbial inoculants to enhance properties such as the taste, aroma, shelf-life, texture and nutritional value of foods. The process by which micro-organisms and their enzymes bring about these desirable changes in food materials is known as fermentation. Fermentation processing is also widely applied in the production of microbial cultures, enzymes, flavours, fragrances, food additives and a range of other high value-added products.

This document synthesizes the key elements of the document ABDC-10/7.1, which evaluates the application of biotechnologies in food processing and food safety in developing countries, considers the reasons for their success or failure in the past and looks at the emerging challenges and future options both for developing countries and for the international community (FAO, UN organizations, NGOs, donors and development agencies).

Stock Taking - Learning from the Past

Fermentation is often one step in a sequence of food processing operations, which may include cleaning, size reduction, soaking, and cooking. Microbes associated with the raw food material and the processing environment serve as inoculants in spontaneous fermentation, while inoculants containing high concentrations of live micro-organisms, called starter cultures, are used to initiate and accelerate fermentation in non-spontaneous or controlled fermentation processes. Microbial starter cultures vary widely in quality and purity.

Fermentation processing as practised in most developing countries is more art than science, and, in low-income economies, often makes use of a rudimentary technological base with poor process control, resulting in low yields and products of variable quality. Spontaneous fermentations and those which make use of "appropriate" starter cultures produced largely through backslopping (a process which makes use of samples of a previous batch of a fermented product as inoculants) are widely applied at the household and village level in developing countries. With increasing research and development, a number of precultured single or mixed strains of micro-organisms, called "defined starter cultures", have been developed and are being used by small manufacturers in their fermentation processing operations. Defined starter cultures are also imported by a number of developing countries for use in processing operations.

Traditional methods of genetic improvement such as classical mutagenesis and conjugation can be applied to improve the quality of microbial cultures. Hybridization is also used for the improvement of yeast strains. Recombinant gene technology is widely employed in research and development for strain improvement. While these techniques are common in developed countries, they are only now beginning to be applied in developing countries for the improvement and development of starter cultures. For example, Random Amplified Polymorphic DNA (RAPD) techniques have been applied in Thailand in the molecular typing of bacterial strains for the production of a fermented pork sausage with differing flavours. The results of these analyses have led to the development of three different defined starter cultures, which are currently used for the commercial production of products with different flavour characteristics.

Genetically modified (GM) microbial cultures are used in the production of enzymes and various food processing ingredients. Rennet, which is widely used throughout the world as a starter in cheese production, is produced using GM bacteria. Thailand currently makes use of GM *Escherichia coli* as an inoculant in lysine production. Many industrially important enzymes such as α-amylase, gluco-amylase, lipase and pectinase as well as bio-based fine chemicals such as lactic acid, amino acids, antibiotics, nucleic acid and polysaccharides are produced in China using GM starter cultures.

Biotechnology is widely employed as a tool in diagnostics to monitor food safety, prevent and diagnose food-borne illnesses and verify the origins of foods. The techniques applied in the assurance of food safety focus on the detection and monitoring of hazards. Biotechnological developments have led to the widespread availability of methods of identification that are more rapid and less costly than those based on conventional techniques. Polymerase chain reaction-based (PCR-based) and enzyme-linked immunoabsorbent assay (ELISA) methods are now applied in the detection of major food-borne pathogens. Genome sequence information, coupled with the support of advanced molecular techniques, have enabled scientists to establish defensive strategies to protect consumers from pathogens and provided industry with tools for developing strategies to design healthy and safe food by optimizing the effect of probiotic bacteria, the design of starter culture bacteria and functional properties for use in food processing. These advances have in turn led to more precise diagnostic tools and the ability to quickly develop efficient, specific and sensitive detection kits for new microbial strains. Kits are now available for the detection also of mycotoxins, which are a major biochemical hazard associated with pulses and grains, the raw material inputs for a number of traditional fermented foods in many developing regions. The identification of food ingredients and the origins of foods through traceability studies have also been enhanced by molecular methods.

Fermented foods are the basis of food and nutritional security in a majority of low-income countries where they are consumed as staples. With growing incomes and improved levels of education in urban centres across a number of developing countries, dietary habits are changing, a wider variety of foods is being consumed and consumers are becoming more demanding. Consumer demand for high-quality safe food and wellness through diet has spurred the development of rapid and sensitive methods for the detection of chemical and biochemical hazards in foods, the tracing of the origins of food and the application of biotechnology for the improvement of starter cultures used in food fermentations. Starter culture development has also

been a driving force for the development of bioreactor technology, designed to improve control over food fermentation processing operations.

The greatest strides in starter culture development have been made in countries that have prioritized the development of technical skills, the provision of infrastructural support and the funding of research into the upgradation of fermentation processes. Linkages between research institutions and the manufacturing sector have also been critical to the successful uptake of starter culture technology. South-South and North-South collaborative initiatives among research institutions have also had a major positive impact on biotechnological developments in developing countries. Biotechnology developments have been most successful where industry has adopted proactive approaches. However, as the food fermentation sector develops, issues relating to the protection of intellectual property rights are of growing concern with respect to starter culture development.

Looking Forward - Preparing for the Future

It is important that countries recognize the potential of fermentation processing for food security, as a means of adding value to meet consumer needs, producing high-value products and assuring the safety and origins of foods. To capitalize on these benefits, countries must put in place the appropriate policies and strategies and create an enabling environment for the development of food fermentations.

Priority must be accorded to promoting fermented foods in the food security agendas of countries. Governments must be committed to protecting consumer health and interests. Research and infrastructural development to enable the cost-effective production of defined starter cultures in a stable format must be given the highest priority. The development of appropriate levels of bioreactor technology for bioprocess control is necessary for the effective use of improved starter cultures. Infrastructure development facilitating the transfer and adaptation of fermentation technologies developed at the laboratory level to the household and village level and, where necessary, to the enterprise level, too, should be prioritized. Appropriate levels of equipment will also be required to facilitate the downstream processing of these products. Traceability systems that facilitate the differentiation and identification of food products should be prioritized in order to broaden market opportunities for these products.

Governments must provide an enabling environment that is supportive of growth and development of upstream fermentation processes such as the production of high value fermented products, including enzymes, functional food ingredients and food additives. In this regard, government policy must prioritise technology transfer designed to create new businesses with supporting measures such as tax incentives and infrastructure.

Food biotechnology must be included in educational curricula in order to improve the knowledge base on the contribution of fermented foods to food and nutritional security. Access to specialized technical information on biotechnology and biotechnological developments in the food processing sector are critical support systems for guiding and orienting the research agendas of countries. Requisite information systems must, therefore, be facilitated across both the developed and developing worlds. Turning ideas and innovation into business ventures is the core model of biotechnology.

A food chain (farm to fork) approach to assuring food safety must be prioritized by governments. Credible national institutions must be established to assure food safety and quality. Legislation must be put in place to establish capacity for assessing food safety risks, priorities for policy intervention and the monitoring and evaluation of food safety risks. The development of biotechnology-based diagnostic tools and services for food safety should be prioritized on the basis of the needs of the sector. Biotechnology capacity development should be an integral part of national science and technology policy. Capacity-building should focus on enhancing scientific and technical skills, particularly at university level. In-country training, as well as overseas training, must be supported by governments in order to develop local technical expertise.

The international community can play a major role in assisting developing countries by strengthening capacities for biotechnology policy development and long-term planning. Funding support must be provided for human resource development, technology transfer, research and development and networking. Support for regulatory frameworks is also essential.

Shoring up regional networks and clusters to provide training and exchange on food biotechnologies, bioprocess engineering and food safety could further co-operation among countries with shared or similar food products. Expertise in biotechnology should be made available within extension, educational, and advisory services to facilitate uptake by both public and private sector users. The setting up of pilot projects and technology transfer has a crucial role in the process. National governments must be facilitated in developing the requisite knowledge base on the development and implementation of intellectual property rights that govern fermentation processes. This assistance should be tailored according to the needs of the specific country and target group.

Public awareness and education about biotechnology is critical to the successful uptake of this technology in food processing and safety. Greater attention must be directed towards understanding and assessing consumer and producer (processor) perceptions on food safety and quality in developing countries. If foods are to be promoted as being safe and healthy, their nutritional and safety attributes must be transparently demonstrated by presenting scientific data to substantiate the nutritional and health benefits and by applying good manufacturing/hygiene practice and Hazard Analysis and Critical Control Point (HACCP) as safety measures to ensure that issues of consumer concern are addressed. The need for specific standards or related texts (Codex/WHO/OIE) and the procedures followed to determine them should also be clearly outlined. The scope of biotechnology use in food processing and safety is vast, and all stakeholders should be involved throughout the process of assessment, identification, adoption and follow-up.