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A Status Note on Food Safety

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A STATUS NOTE ON FOOD SAFETY[1]

Summary

In view of the CGIAR's identification of food safety as an area requiring priority attention to safeguard the economic interests of smallholder farmers and the poor, this document aims to provide a general overview of the level of research and development attention accorded by the scientific and development community to this theme. This baseline survey of work undertaken exposes: the nature of the problem; the food safety situation of the poor; food safety concerns in technology and policy research in the CGIAR; the role of capacity-building; and subsequently attempts to provide pointers to the CGIAR research community along which it could proceed. The level of attention to food safety stems from: the increased incidence of food-borne illness worldwide; food safety governing national productivity by way of both household and community health as well as by capitalizing on export potential.

Fulfilment of food safety standards are becoming more a function of the level of involvement in international agricultural trade as well as of the degree of development of the agro-processing industry.

Food safety considerations in research can be taken into account at both the production and post-harvest stages. The primary candidates for research should be the traditional crops relevant to small farmers and poor consumers in developing countries (banana, cassava, yam, sweet potato, rice, maize, wheat, millet) in their specific ecological, socioeconomic and cultural contexts. The potential income benefits from farming could be more fully realized by reducing post-harvest losses to maximize utilizable production for diversified end-uses. With increased emphasis on “utilizable” production, germplasm enhancement, likely to assume added importance, has to duly incorporate criteria such as suitability for processing and toxicity content.

The use of biotechnology can lead to improved food safety by: reducing pesticide use and enhancing the post-harvest keeping quality of products. The same technology, however, may pose health risks due to possible transfer of toxins and allergens between species, calling for systematic testing under a strict regulatory environment.

There is a glaring lack of relevance of private sector agricultural research in developing countries to the genuine needs of the poor. For the private sector to engage in pro-poor research and for developing countries to gain access to relevant biotechnologies originating in the North, Intellectual Property Rights need to be duly respected. The public sector and CGIAR Centres, playing the role of "honest broker", could offer to buy exclusive rights to newly developed technology, including genes, to make it available at little or no cost to small farmers.

Managing food safety requires more than technological infusion: it calls for an enabling policy environment and capacity building to provide the requisite administrative manpower to cope with standards. The Hazard Analysis and Critical Control Point (HACCP) system

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[1] Background paper prepared by Amir Kassam (TAC Secretariat) and Saurav Barat (TAC Secretariat Consultant) as a source of information for TAC/SCOPAS for discussion on food safety concerns in the CGIAR. Helpful guidance was received from Joachim von Braun.

principles, as adapted to the developing country context, could serve as an ideal model for managing risk along the entire production-consumption continuum.

It is clear that within the CGIAR System, there has been no set strategy to provide guidance on the topic and that work done to date has been largely of an ad hoc nature. The formulation of such a strategic framework is now essential, and would naturally prevent duplication, capture synergies from the currently isolated activities and promote greater efficiency.

1. Introduction

Food safety is becoming a dominant theme among the agricultural research and development community, due to: (1) its linkage with national food security, agricultural and rural development and international agricultural trade; and (2) recent advances in molecular biology and biotechnology, which offer new opportunities amid differences of perception concerning genetically modified foods.

The CGIAR has recently identified food safety as a topic of priority concern to ensure that smallholder farmers in developing countries duly benefit from scientific advances in the field and also to prevent their marginalization due to food safety concerns in the process of globalization. TAC, at its 80th Meeting in March 2001, requested its Standing Committee on Priorities and Strategies (SCOPAS) to develop a proposal to review food safety considerations in CGIAR research. To lay the ground work for such a proposal, this background paper was prepared by TAC Secretariat to constructs a representative baseline on the topic focussing on: the nature of the problems encountered, the regulatory environment and its trade implications and, particularly, a sampling of the type of research undertaken by the CGIAR Centres to date.

Food safety is of primary concern to FAO and WHO. However, there appears to be no standard definition of food safety. **FAO defines it as *providing assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use*** (**FAO, 1996**). ***WHO talks in terms of food-borne illness defined as diseases, usually either infectious or toxic in nature, caused by agents that enter the body through the ingestion of food.*** Every person is at risk of food-borne illness. Encompassing issues of health and nutrition emanating from consumption of food, food safety thus is a reflection of the qualitative worth of food. For the purpose of this discussion, any nutritional or quality enhancement of food that was already safe is also considered relevant. The clearest manifestation of consumption of unsafe food is infectious or toxic diseases caused by food-borne pathogenic agents. Food safety is a function of the nature of technology used to produce and process food. As such, it can be manipulated through genetic improvement, agronomic practices and post-production storage and processing. Utilization and consumption of safe food is a key component of food security at the household level, the two other components being food availability through production, and access to food through purchasing power.

This note first presents the nature of the food safety problem. It then assesses, based on a literature survey, the treatment of food safety by international agencies such as FAO, WHO, World Bank, synthesizing the state-of-the-art. Attention is then focused on food safety considerations in technology improvement research by a sample of CGIAR Centres, categorized under production research and postharvest research. The next two sections deal with policy research and capacity building to cope with food safety. Finally, an attempt is made to point toward possible areas of future research attention for the CGIAR.

2. Nature of the Problem

Food is the major source of human kind's exposure to pathogenic agents, both chemical and biological (viruses, parasites, bacteria), from which no individual in developing and developed countries alike is spared. The importance of food safety stems from:

1. food being a huge disease burden both in the developing and the developed world, being the primary mode of transmission of disease-causing agents (bacteria, viruses, other germs); and
2. the intricate linkage with development: it not only governs individual and community health, and thereby national productivity, but also promotes export potential and thus foreign exchange.

Food safety has also emerged as one of the most prominent sources of conflict in international agricultural trade, sharply heightening concern in the past decade in both Europe and the US. However, the highest number of rejections, due to food safety, concerns food originating from developing countries. The most frequent violations are contamination by insects, followed by microbial contamination and excessive levels of pesticide residue. The fastest growth rate in trade has occurred among high value perishable products, for instance fresh and minimally processed fruits, vegetables, meat and fish. Product perishability and demand for year-round food availability have raised the stakes for food safety. The markedly facilitated spread of pathogens associated with the increase in food trade between developing and industrialized countries has caused food safety to be treated as an issue of global trade rather than of public health.

In the global context, the already high number of sufferers of food-borne illness is growing side-by-side with increased public awareness of food safety due to the following factors: the emergence of new pathogens, aging of the world's population, increased urbanization, growing consumption of non-traditional foods and increased international travel.

Even in developed countries, up to one out of three consumers contracts disease from food-borne pathogens each year, with up to 20 person per million perishing from such diseases. In many industrialized countries, the last few decades have seen a rising trend in diseases such as salmonellosis, campylobacteriosis and infections caused by *E. coli* O157:H7. In the US, for instance, around 76 million cases of food-borne illness, resulting in 325,000 hospitalizations and 5,000 deaths, are estimated to occur each year (WHO, 2000). The estimated incidence of salmonellosis alone is 20 cases per 100,000.

The total extent of the food-borne disease problem in the developing world is likely higher but difficult to estimate since its victims often cannot track down the cause and do not seek medical attention. Besides, medical systems in most countries are ill equipped to monitor outbreaks. Regularly falling prey to food-borne diseases such as cholera, diarrhoea and Hepatitis A, it is here that the real tragedy manifests itself.

Diarrhoea is the most common symptom of food-borne (and water-borne) illness and a major cause of malnutrition in infants and young children. Of the 1.5 billion children under age 5 who are affected by diarrhoeal diseases annually, 70% being caused by biologically contaminated food and unclean water, 3 million die prematurely, mainly in developing countries. For adults, the number of deaths and illnesses is likely to be huge. No less significant are food-borne parasitic diseases: for instance, food-borne trematodes affect 40 million people, with more than 10% of the world's population at risk of infection. Transmission to humans occurs through consumption of raw or inadequately processed freshwater fish and shellfish grown in endemic areas, as well as contaminated aquatic plants. As for chemical contamination, the little published information from developing countries indicates a significant exposure of the general population to pesticide residues in food.

Other causes of unsafe food are: weak agricultural and transportation infrastructure, resulting in poor storage techniques; non-functional sewage and sanitation systems in rapidly expanding urban areas; the poor hygiene and storage practices of street vendors on whom poor migrant workers must depend; and public ignorance of safe storage and preparation techniques.

The incidence of food-borne illness is clearly increasing worldwide, particularly so in many industrialized countries during the last few decades, for instance salmonellosis, campylobacteriosis and infections caused by *E. coli* O157:H7. In the USA, the estimated incidence for salmonellosis alone is 20 cases per 100,000 with an estimated 7,000 deaths per year. Food-borne illness opens a vicious circle: the associated under nutrition causes immune deficiencies, which, in turn, increase vulnerability to other infections.

Major Food-borne Diseases from Micro-organisms:

The following are the main food-borne diseases from micro-organisms.

- **Salmonellosis**, a major problem in industrialized countries, is caused by the *Salmonella* bacteria and symptoms are fever, headache, nausea, vomiting, abdominal pain and diarrhoea. Examples of foods involved in outbreaks of salmonellosis are eggs, poultry and other meats, raw milk and chocolate.

- **Campylobacteriosis**, a widespread infection, is caused by certain species of *Campylobacter* bacteria; in countries such as Denmark, Sweden, Finland, Norway, Netherlands, UK, its incidence surpasses that of salmonellosis (BGVV, 2001). Food-borne cases occur in raw milk, raw or undercooked poultry and drinking water. Acute health effects of campylobacteriosis include severe abdominal pain, fever, nausea and diarrhoea. In 2-10% of cases, the infection may lead to chronic health problems, including reactive arthritis and neurological disorders.

- **Pathogenic *E. coli* strains**, such as *E. coli* O157 which produce a potent (vero-) toxin, cause haemorrhagic infections in the colon, resulting in bloody diarrhoea or life-threatening complications such as kidney failure. Such bacterial strains together with listeriosis, although having a low incidence, exhibit severe and sometimes fatal health consequences, particularly among infants, children and the elderly. Although E. *coli* O157 outbreaks have been mainly related to beef, sprouts, lettuce and fruit juice have also been linked. *Listeria monocytogenes,* the cause of listeriosis, produces a fatality rate of up to 30%. The most frequent effects are meningitis and miscarriage or meningitis of the foetus or newborn.

- **Cholera** is a major public health problem in developing countries, caused by *Vibrio cholerae*, a bacterium. Both water and contaminated foods can be the vehicles of infection. Past outbreaks have involved different foods, including rice, vegetables, millet and various types of seafood. Symptoms, including abdominal pain, vomiting and profuse watery diarrhoea, may cause severe dehydration and possibly death, unless fluid and salt are replaced.

Other Food Safety Problems:

Some major examples are the naturally occurring toxins, unconventional agents, persistent organic pollutants (POPs) and metals.

- **Naturally occurring toxins,** such as mycotoxins, marine biotoxins, cyanogenic glycosides and toxins occurring in poisonous mushrooms, periodically cause severe intoxication. Mycotoxins, such as aflatoxin and ochratoxin A, are found at measurable levels in many staple foods; the health implications of long-term exposure are poorly understood.
- **Unconventional agents** such as prions, associated with cattle suffering from *Bovine Spongiform Encephalopathy* (BSE, or "mad cow disease"), are suspected to cause new variant Creutzfeldt-Jakob Disease in humans. Consumption of meat and meat products is the channel of transmission to humans.
- **Persistent organic pollutants (POPs):** Dioxins and Polychlorinated Biphenyls (PCBs) exist in the environment and in the human body. Dioxins are carcinogenic by-products of many industrial processes and waste incineration, having pronounced toxic effects on reproductive and nervous systems.
- **Metals,** such as lead and mercury, cause neurological damage in infants and children. Exposure to cadmium can also cause kidney damage, usually seen in the elderly. Pollution of air, water and soil may cause food contamination with POPs and metals.

Health risks posed by microbial pathogens and potentially hazardous chemicals in food, given their detrimental impact on the national economy, are of major concern to all governments. The enormous social and economic burden of food contamination on communities and their health systems is exemplified by the USA, where diseases caused by the major pathogens alone are estimated to cost up to US $37.1 billion annually in medical costs and lost productivity (WHO, 2000). The BSE epidemic in Britain and dioxin contamination scandal affecting meat and poultry in Belgium served to polarize public opinion against the reliability of existing control systems to ensure food safety: regulatory agencies initially failed to detect the seriousness of the respective food safety problem and then sought to downplay its likely consequences. Shortcomings in monitoring over changes in the production process of ruminant bone and meat meal used as a feed supplement for cattle might have caused BSE to emerge. The dioxin contamination scandal involved the use of animal fat contaminated with industrial oil in livestock feed.

Food Safety Concerns Related to Biotechnology:

Many developing countries, still depending heavily on agriculture, stand to benefit disproportionately from any technology that can increase food production, lower food prices, and improve food quality.

Modern biotechnology, allowing genetic modification of plants, micro-organisms and animals for food production and processing, offers much potential to meet the food security needs of the expected 8.1 billion people by the year 2030, particularly on less favourable lands under a “low inputs” regime. The benefits derived, among others, are increased yields, greater resistance to pests and diseases, reduced use of chemicals, increased content of essential nutrients and prolonged shelf life. Genetic engineering may well improve food safety by removing toxic compounds naturally present in plants, for instance removal of cyanogenic glycosides from cassava and toxic lectins from kidney beans (Butler et al., 1999). The engineering of useful traits in elite cultivars of corn, soybean, cotton and rapeseed have led to high-performance novel crops, which have passed all the agronomic, food hazard and environmental safety tests. These crops have been commercialized since 1996, and in 1998, 30 million ha were grown, mostly in the US, Canada, Argentina and China. In 1999, globally, some 40 million ha were planted under transgenic crops, a 44 % increase from 1998 (De Haen, 2000).

This same technology, however, can pose certain risks: while the world's major regulatory and scientific agencies allege genetically modified (GM) crops pose no greater threat to human health than those produced by traditional breeding, critics of gene technology argue that the remote and real risks potentially associated with accelerated plant breeding brought on by developing genetically modified plants merit serious consideration. Examples are: safety of antibiotic marker genes in some genetically modified foods, their use possibly being unnecessary due to availability of innocuous alternatives; the possible transfer of toxins or the creation of new toxins from one species to another; the possible presence within genetically modified foods of allergenic proteins introduced from external sources (insertion of an allergy-causing peanut gene to create transgenic soybeans); the risk from the vector used to engineer plants, viz. *Agrobacterium tumefaciens*; uncontrolled inter-breeding between the genetically-modified plant and its wild relatives, with far-reaching repercussions for global biodiversity given that developing countries are the centres of origin of many of the world’s leading food crops. Aside from the above, with much of applied biotechnology research being concentrated in the private sector, concern has been raised regarding its control over genes that were originally in the public domain.

If the potential benefits of GMOs are disproportionately large in developing countries, so are the potential costs. Most developing countries lack the economic expertise to evaluate their worth, the scientific capacity to assess their safety or the regulatory capacity to implement guidelines for safe deployment and enforce sanctions against transgressors.

Consumers on either side of the Atlantic differ greatly in their trust of food safety regulation systems. Americans in general have faith in their government’s ability to protect them from unsafe food products. US regulatory organizations are widely supported: 90% of Americans support the USDA, and 84% support the FDA. European regulatory agencies, by contrast, are viewed with suspicion: for instance, only 4% of Europeans say national public bodies can be counted on to be completely transparent about transgenic crops. Besides, the rather marginal benefits to consumers, vis-à-vis producers and processors, are at the root of consumer resistance to GM products. It also bears mention that relatively little biotechnology research focuses on the productivity and nutrition of poor farmers and consumers in developing countries, except for maize: the challenge lies in shifting from the scientific foundation created by industrial country-oriented research to the poor’s needs.

New scientific methods to assess the safety of food derived from biotechnology have yet to be developed and agreed upon internationally. Full-scale introduction of the next generation of GM crops including "functional foods", for instance plants with increased vitamin levels, would be contingent on safety trials analogous to clinical trials for assessing safety of drugs. Investigations would cover: the safety of the gene introduced and the protein it expresses; any consequent change in plant metabolism and associated increase in toxins; the breakdown *products* after degradation of proteins by plant enzymes. In addition, 'silent' or lowly-expressed genes might be "switched on". Although rigorous food safety tests prior to approval of crops produced by genetic modification minimize any risk, the need for vigilance remains constant.

In assessing the risk of foods developed by the application of modern biotechnology, the concept of **substantial equivalence** was first introduced in 1993 by OECD, and was endorsed in 1996 by FAO and WHO. If a GM food can be characterized as substantially equivalent to analogous conventional foods in terms of toxicity, nutritional quality, it can be assumed to pose no new health risks and hence to be acceptable for commercial use. However, the concept is controversial: it is allegedly inherently unscientific, since it is only a pretext for not requiring biochemical or toxicological tests, thereby discouraging potentially informative scientific research. It has been erroneously stated that Glyphosate-tolerant soybeans are substantially equivalent to non-GM soybeans, when it is an established fact that the very application of Glyphosate to soybean significantly changes its chemical composition (Millstone *et al.*, 1999).

The modern approach to food safety in the developed world is to rely on prevention at every stage of the food chain, from farm to the table, the essence of the **Hazard Analysis & Critical Control Point (HACCP)** system, already adopted by EU, USA, Australia, New Zealand and Canada. Application of HACCP principles is held as a pre-requisite for developing countries to gain entry into the industrialized markets. Besides, technical assistance is being provided to developing countries toward aligning their domestic food safety controls along HACCP lines.

3. Food Safety Situation of the Poor

Rural Poor: As too well known, even developed countries with high food standards and sophisticated inspection and control systems occasionally experience serious food contamination and health hazards, although not always detected. Such hazards are attributed to, among others, microbiological contamination, contaminants entering the food chain from transboundary exchange and residues of inputs used in production/processing systems. Of greatest concern is the high level and rising trend of food-borne diseases of microbiological origin, possible at all stages of the food chain. Equally worrisome is the increasing resistance of food-borne pathogens.

The risk to food safety is even higher in low-income developing countries, where low agricultural productivity is a major cause of poverty, food insecurity and poor nutrition among both the urban and rural poor. Seventy-five percent of the world's poor live in developing country rural areas, with agriculture being the economic backbone. Low incomes and associated low purchasing powers increase the chances of consuming food of poorer quality that may well be also unsafe. This relationship is amplified in the case of low potential marginal lands, for instance the arid and semi-arid lowlands and highlands. Here, the sequence of "knock-on" effects may be insufficient access to safe water and essential facilities for safe food preparation, poor water management causing soil erosion, leading to low productivity and, in turn, low incomes.

Urban Poor: Since the 1950s, the average size of the world's biggest cities has more than doubled. By 2015, more than half the world's population will live in urban areas. This unprecedented growth in urban populations renders urban and peri-urban farmers more and more important. Today an estimated 800 million people are engaged in some form of urban and peri-urban farming, whether tending home gardens or working in larger-scale livestock, aquaculture, forestry, or greenhouse operations. Urban and peri-urban food production can improve family health and expand income options for women with children. Yet, it can also present risks, from the spread of animal-borne diseases to the contamination of drinking water. CIP has taken on a leadership role within the CGIAR in focusing attention on the needs and potential contributions of urban and peri-urban agriculture.

For the relatively better off urban population segments, increased income and a shift away from cereal-based diets would likely generate a demand for fish, livestock, horticultural, forest produce as well as processed items in general, in turn necessitating creation of associated transport, storage and marketing infrastructure. In the case of tropical fruit, availability of improved storage technology opens new markets for higher value products from developing country rural areas, capitalizing on which increases the incomes of the rural poor.

The demand for livestock products could double during the next 15-20 years, translating into a need for both increased quantity as well as quality that can be traded locally and globally. Of the 75 % of the poor living in developing country rural areas, 66% keep livestock, the enhanced demand offering them an avenue to escape the poverty trap. However, epidemics such as *Bovine Spongiform Encephalopathy* (BSE), Foot-and-Mouth Disease, and Classical Swine Fever, recent occurrences of which in Europe have pinpointed the impact of food safety on human health let alone the economic loss, still occur in developing countries, posing a continuing food safety threat to the industrialized world through trade.

However, the vast majority of developing country urban dwellers remain disadvantaged with limited purchasing power, calling for efficient distribution of low-cost, easily prepared but safe food. Malnutrition may arise from the poor's consumption of unsafe food, but may prevail even in the presence of safe food, if the requisite health and sanitation services are unavailable. Accessing health services requires household income growth through technological intensification, commercialization of agriculture and off-farm income-generating activities (von Braun *et al*., 1991).

4. Treatment of Food Safety by International Organizations

4.1 Food and Agriculture Organization (FAO)

Within FAO's objective of ensuring food for all through improved efficiency of production and distribution of food and agricultural products, food safety is a key plank. The Division with primary responsibility in this area is the Food Policy and Nutrition Division, Economic and Social Department. However, many food safety activities are interwoven into programmes undertaken by FAO's Agriculture and Fisheries Departments. The main food safety activities, many of them implemented jointly with other international organizations, are: CODEX Alimentarius Commission (with WHO), further elaborated below; safety evaluation of food, agricultural and veterinary chemicals (with WHO); the International Code of Conduct on the Distribution & Use of Pesticides; the Code of Conduct for Responsible Fisheries (CCRF); the Rotterdam Convention on Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade. The CCRF requires states to safeguard the rights of consumers to safe, wholesome and unadulterated fish and fishery products, backed up by national safety and quality assurance systems.

FAO provides expert advice to develop and operate, based on a national strategy, efficient national food control systems, covering, among others, food sampling and inspection. It also assists countries in reviewing and updating food legislation in light of the WTO's SPS and TBT Agreements; the Model Food Law developed jointly by FAO and WHO, and CODEX standards and guidelines. The organization has implemented projects specifically relating to national food export inspection and certification programmes in India, Indonesia, Thailand and Costa Rica. The project in India also included training of food export inspectors (Lupien, 1997). FAO has also assisted countries to strengthen their respective National CODEX Contact Points and National CODEX Committees. Furthermore, through its decentralized structure, FAO administers an extensive education and training programme on food safety.

Food safety is well reflected as a recurring theme in FAO's regional work programmes. In ***Africa***, during 1999, FAO provided technical assistance to 22 countries toward upgrading the quality and safety of food sold and consumed. With World Bank support, food quality control missions were fielded to Côte d'Ivoire, Senegal, Mali, Mauritania and Ghana. Also, FAO collaborated with the Rotary International Hunger, Health and Humanity Programme, the government of the USA, France, and IITA to establish a Mycotoxin Training Network (FAO, 2000a). Assistance is being provided to Nigeria, Senegal and South Africa to improve the safety of street foods. Similar programmes are being designed for Burkina-Faso, Mali, Gabon, Mauritania and Cape Verde.

The Organization assisted member countries to improve the quality and safety of fishery products through: a national workshop organized in Senegal in April 1998; training in Guinea, Uganda and COMESA countries in June 1999; and workshops on fish technology and quality assurance organized in Walvis Bay, Namibia and in Libreville, Gabon in September 1999.

Concerning *Asia* regional food quality and safety activities during 1998-99, FAO, in collaboration with the International Life Sciences Institute (ILSI), organized a workshop on science-based harmonization of food quality and safety measures, and convened a regional seminar on improving the hygienic and sanitary aspects of street food establishments in September 1999 in Thailand (FAO, 2000b). Other activities included a sub-regional workshop in India on various aspects of food control and a separate one in Thailand in August 1999 on food control organization and risk assessment. The 12th session of the Codex Coordinating Committee for Asia overseeing food additives and contaminants was held in Chiang Mai in November 1999. A separate workshop was organized on the administration of national Codex Committee in the Philippines.

In the Asia region, microbiological biotechnologies serve to add value to agricultural biomass resources and for diagnostic purposes in assessing quality and safety of foods, in particular fermented foods which are widely consumed by the rural poor (FAO, 2000c). In Thailand, for example, Random Amplified Polymorphic DNA (RAPD) techniques are being applied to the precise identification and selection of microbial strains for the development of starter cultures and cell banks for the production of fermented foods.

The Asia-Pacific Fishery Commission (APFIC), in its effort to translate research results into effective management options, established a working group to deal with issues concerning food safety from fish products and rural aquaculture. The APFIC also reviewed the current situation on pathogenic and parasitic infections from fish and fish products. In collaboration with the Support Unit for International Fisheries and Aquaculture Research, FAO organized two regional workshops to identify research needs concerning food safety in sustainable fish production in the region, in particular preventing and controlling human fish-borne trematode parasite infections. Specific research on pathogens in the aquatic environment and studies on antibiotic resistance of bacteria associated with aquaculture systems were identified as areas of further collaboration among research institutions in the region (FAO, 2000b**)**.

As for ***Europe*****,** the 2000 European Regional Conference supported the "farm to fork" approach to food safety which would require food operators throughout the food chain to be responsible and accountable for the safety of their products. It recognized that the application of good manufacturing practices, good hygienic practices and quality assurance systems such as the Hazard Analysis and Critical Control Point (HACCP) system, were essential to preventing food safety risks and in ensuring consumer protection; feed borne hazards could be decreased if feed production were subject, in the same way as food production, to quality assurance based on HACCP. The Conference emphasized traceability for all food- and feed-chains and their ingredients to be an essential requirement of food safety systems, and made a distinction between risk assessment and risk management. While non-use of synthetic pesticides and chemical fertilizers enabled organic foods to offer distinct health advantages, the use of organic fertilizer could be a source of microbiological contamination of primary produce, just as in conventional farming (FAO, 2000d).

Concern about safety of foods of animal origin had heightened due to problems arising from BSE, dioxin contamination, outbreaks of food-borne bacterial infections as well as veterinary drug residues and microbial resistance to antibiotics. There was a real fear over the contamination of animal feed by mycotoxins, agricultural and industrial chemicals, and heavy metals. The issues governing the quality and safety of foods of animal origin varied considerably across the different regions of the world due to the widely differing livestock production systems. Toward improved animal health and welfare, anti-microbial growth promoters were to be phased out, gradually to be substituted by non-anti-microbial alternatives. Specifically on animal feedstuffs, a negative list of raw materials was to be established and the use of undesirable ingredients was to be minimized to ensure better consumer protection. The Conference underlined the importance of an international monitoring programme on feed contaminants accompanied by the necessary institutional and capacity building.

The European Commission was planning for a comprehensive food safety strategy for the coming years as contained in the "White Paper on Food Safety" issued in January 2000. It also sought to: establish a European Food Authority (EFA); engage in scientific risk assessment; and set up a rapid alert system connecting control authorities across Europe.

In the ***Latin America*** region, increased urbanization and changes in the labour market are generating a series of new technological demands in terms of processed foods, with a premium on quality and safety, obliging countries to adopt strict control standards (FAO, 2000e).

4.2 World Health Organization (WHO)

The WHO is the UN agency with the specific mandate of protecting public health. Long recognizing that an important pre-requisite to attaining the highest possible health level is access to safe food, the organization seeks to protect the consumer from food-borne hazards. It has a long history of providing advice to the Codex Alimentarius Commission and to member states on assessment of food-borne health hazards.

WHO's food safety work is coordinated and implemented at Headquarters by Food Safety Programme, Department of Protection of the Human Environment, Cluster on Sustainable Development and Healthy Environments (FOS/PHE/SDE) and, at the regional and country level, by Regional Advisors. Areas in which WHO is particularly active include:

1. ***Development of national food safety policies and infrastructure on the basis of local needs assessment***. Its most important role is a normative one, developing a risk analysis framework for managing public health risks in food and water, and thus helping define public policy concerning safety of the food supply.
2. ***Food legislation and enforcement*** (also referred to as 'food control'), which encompasses components such as (a) food standards and codes of hygienic practice; (b) inspection services and laboratory analysis; and (c) promotion and training in the Hazard Analysis Critical Control Point (HACCP) system as a food safety management tool.
3. ***Increasing awareness of food processing technologies*** that will assist in decreasing post-harvest spoilage and preventing food-borne disease.
4. ***Education of households/consumers in hygienic handling*** of food and basics of food sanitation through liaison with primary health care worker who, by educating and informing mothers, plays a key role in the promotion of safe weaning food and the prevention of diarrhoea in infants and young children.
5. ***Improving the hygienic quality of street-vended food*** and food served in food service establishments. In addition, food safety is a major theme of the "healthy marketplaces" initiative carried out under WHO's Healthy Cities Project.
6. ***Epidemiological surveillance*** of food-borne diseases, monitoring of chemical and other contaminants in food as well as food safety infrastructure. As part of its Surveillance Programme on Food-borne Diseases and human exposure to chemicals through food, WHO, since 1976, in conjunction with FAO, IAEA, UNEP and national bodies, has been implementing the *Global Environment Monitoring System - Food Contamination Monitoring & Assessment Programme* (GEMS/Food), which provides information on the levels and trends of major contaminants in food, including anti-microbial resistant food borne bacteria, and their implications for human health. Through regional training courses in anti-microbial resistance, the surveillance initiatives focus on strengthening capacity of national Salmonella/Salmonellosis reference labs. WHO, in collaboration with FAO, is developing internationally agreed methodologies for microbiological risk assessment. In addition, an INTERNET clearinghouse mechanism for Microbiological Risk Assessment information is planned to be jointly established. Compiling and synthesizing data from some 70 countries, the GEMS supports risk management activities of the Codex Committee on Food Additives and Contaminants (CCFAC) and the Codex Committee on Pesticide Residues (CCPR). Two key sources of reference utilized are: *Guidelines for*

Strengthening Integrated National Food-borne Disease Surveillance Systems and *WHO-Recommended Surveillance Standards to Food-borne Diseases*.

The WHO Executive Board in January 2000 came up with recommendations that, subject to approval at the World Health Assembly later that year, it would set the future direction for WHO's food safety activities. It announced a plan for the expansion of its food safety programme in response to new challenges. New proposed activities are: creating a risk assessment body with FAO to review the most important micro-organisms in food; generating more comprehensive data on food-borne diseases; defining research activities to assess health implications from consumption of Genetically Modified foods; promoting more synergy between national health and agriculture bodies; and maximizing use of information on risk assessment from developing countries for international standard-setting. During 2000, work began on the development of guidelines for hazard characterization of microbiological pathogens in food and water, due for completion in 2001. Also in 2000, WHO and FAO initiated risk assessments for *Salmonella* spp. in broilers/eggs and *Listeria monocytogenes* in ready-to-eat foods. In 2001, work has begun on *Vibrio parahaemolyticus* in fish, *Vibrio cholerae* in industrialized and locally produced food as well as on *Campylobacter jejuni* in poultry. In 2002, work will commence on two additional pathogen commodity combinations, this pattern to be repeated each year.

4.3 CODEX Alimentarius Commission (CAC)

FAO and WHO established the CAC in 1961-62 to implement the Joint FAO/WHO Food Standards Programme aimed at: a) protecting the health of consumers and ensuring fair practices in food trade; and b) coordinating all food standards work among international governmental and non-governmental organizations. The Commission develops international standards, codes of practice and guidelines governing safety and quality of foods entering into international trade. As of May 2000, it had: developed 240 standards covering processed, semi-processed or raw foods destined to the consumer; formulated 40 hygienic and technological Codes of Practice; evaluated 80 veterinary drugs and over 1,200 food additives; established over 3250 Maximum Residue Levels (MRLs) for pesticides; and specified 25 guidelines for contaminants. These values are treated as reference points by the Sanitary and Phyto-Sanitary Standards (SPS) agreement of the WTO.

While the use of food additives can improve the quality, quantity and safety of the food supply, appropriate controls are necessary to ensure their proper application. At the forefront of current scientific knowledge on risk assessment of food chemicals are: the Joint FAO/WHO Expert Committee on Food Additives (JECFA), which also oversees veterinary drugs; and the Joint FAO/WHO Meeting on Pesticide Residues (JMPR), establishing MRLs for pesticides. The International Programme on Chemical Safety (IPCS), a joint programme of WHO, UNEP and ILO, encompasses the JECFA and JMPR.

The CAC meets once every 2 years to adopt/draft standards, Codes of Practice and guidelines, as proposed by its subsidiary bodies. Among the subsidiary bodies, there are eight primarily concerned with food safety: individual CODEX Committees on Food Hygiene, Food Additives, Contaminants, Pesticide Residues, Residues of Veterinary Drugs in Foods, Meat Hygiene, together with two inter-governmental Task Forces, one on Foods Derived from Biotechnology and the other on Animal Feeding. Separate CODEX Committees exist for: Fish and Fishery Products; Methods of Sampling and Analysis to ensure food safety; and food labelling. The Task Force on Biotechnology, a forum of government regulators, at its first meting in Japan in March 2000, agreed on a 4-year plan to develop broad, general risk analysis principles for bio-engineered foods, noting long-term health impacts and unintentional effects of genetic modification, soliciting involvement of all stakeholders in the decision making process.

Risk Analysis, pertaining to general food safety principles, and first discussed officially in 1993, is handled by the CODEX Committee on General Principles, the most appropriate body to clarify food safety terminology such as *precautionary principle* and *precautionary approach*. It encompasses Risk Assessment, Risk Management and Risk Communication.

Risk Assessment: The World Trade Organization Sanitary and Phytosanitary Standards Agreement introduced this concept in 1995, which was further endorsed by the Codex Alimentarius. It is guided by two independent scientific committees: the Joint Expert Committee on Food Additives (JECFA) and the Joint Meetings on Pesticide Residues (JMPR).

The JECFA, an independent expert committee created in 1956, provides technical inputs concerning additives, chemical contaminants, veterinary drug residues and natural toxicants such as mycotoxins. Through toxicological evaluations, the JECFA establishes an Acceptable Daily Intake (ADI) for a food additive, a Provisional Tolerable Weekly Intake or Provisional Maximum Tolerable Daily Intake for chemical contaminants as well as an ADI and MRL for veterinary drugs. Safety data on food additives, contaminants and veterinary drugs reviewed by JECFA are published as Toxicological Monographs in the WHO Food Additive Series (FAS).

The JMPR, an independent scientific committee comprised of the FAO Panel of Experts on Pesticide Residues in Food and in the Environment and the WHO Core Assessment Group, undertakes toxicological evaluations of pesticide residues to arrive at an Acceptable Daily Intake (ADI). Besides, it recommends MRLs for individual pesticides on specific commodities.

WHO, at the *Conference on International Food Trade Beyond 2000*, recommended that, under FAO's advice, the following be updated and harmonized between JECFA and JMPR: approaches used to calculate dietary intakes of pesticide residues; and principles for toxicological evaluation of food chemicals (natural constituents, additives, contaminants, pesticide residues).

Given the potentially significant impact of food-borne biological hazards, the CODEX Committee on Food Hygiene has come up with risk assessments of biological agents (bacteria, viruses, helminths), backed up by the creation of an expert advisory body and international strategy on assessing microbiological risk.

On biotechnology, in the absence of a specific provision within CODEX for risk assessment of novel (including bio-engineered) foods or a Standing Committee for biotechnology, CODEX, in 1999, set up an *ad hoc* Inter-governmental Task Force on Foods Derived from Biotechnology, charged with developing, on the basis of scientific evidence, guidelines, standards and recommendations concerning traits introduced into foods through biotechnology. A set of broad general principles of such risk assessment was being elaborated. Guidelines for transparent decision making and for the participation of all stakeholders in this process were also under development. Future decisions covering human health and nutrition aspects of bio-engineered foods are entrusted to FAO and WHO, who were in the process of creating a roster of food safety experts. JECFA's mandate could be broadened to include such foods. The CODEX Committee on Food Labelling is developing labelling recommendations for biotechnology-derived foods.

Risk management concerns the weighing of policy alternatives for risk prevention and control to protect the health of consumers and to promote fair trade. In 1995, the CAC adopted four statements of principle concerning the role of science in the CODEX decision-making process and the extent to which other legitimate factors are taken into account in health protection and fair trade. Risk management is guided by these Statements of Principle.

When formulating national and international standards, the *FAO Conference on International Food Trade Beyond 2000: Science-Based Decisions, Harmonization, Equivalence & Mutual Recognition* concluded precaution has and should remain a guiding principle in Risk Management, particularly when there is insufficient scientific evidence of potential unknown negative impacts. Furthermore, the CAC was the ideal forum for deliberating on the topic. The WTO SPS Agreement also embodies the *Precautionary Principle*.

Risk communication is the interactive exchange of information in this area among all stakeholders: risk assessors, risk managers, consumers, industry and academia, eventually promoting better consumer education and improved food safety, as stipulated by the Codex General Principles of Food Hygiene. FAO and WHO have taken the lead in global and regional communication concerning food-borne risk.

Based on special requests from member countries or the Commission, *ad hoc* expert consultations are convened jointly by FAO and WHO on various food quality and safety aspects. Two such meetings have been *Biotechnology and Food Safety* in Geneva in 1990 and in Rome in 1996; and the *International Conference on Mycotoxins* in Tunisia with UNEP in 1999.

As for Food Irradiation, FAO, IAEA and WHO jointly established the International Consultative Group on Food Irradiation (ICGFI) in 1984. Two key food safety publications of this group are *Enhancing Food Safety through Irradiation* and the *Safety of Poultry Meat: from Farm to Table*, both published in 1999.

In June 1999, the CAC set up an *ad hoc* Intergovernmental Task Force on Animal Feeding to elaborate guidelines and standards for animal feeds, with a view to safety and quality of foods of animal origin. FAO had previously, in 1997, produced a draft Code of Practice for Good Animal Feeding, encompassing procurement, handling of pre-production ingredients, manufacturing, post-production storage and distribution.

CAC membership is open to all member nations and associate members of FAO and WHO; it currently stands at 165 countries. Administrative support is provided by a Secretariat within FAO. A decision to elaborate a new or revised standard is taken in consultation with member governments, striking a consensus. The Commission has encouraged the involvement of consumers in standard-setting activities.

4.4 World Bank

Food safety is a relatively new area for World Bank involvement: as of August 2000, there were only 66 Bank projects with any food safety component (in the ESSD core database), mainly in the form of agricultural projects with animal and plant health components (World Bank, 2000). In designing and implementing new projects, the Bank can draw upon other institutions with expertise in food safety, namely FAO, WHO, and bilateral assistance from major industrial country importers.

4.5 World Trade Organization (WTO)

In the WTO's *Sanitary and Phytosanitary Standards* (SPS) Committee, the CAC holds observer status. Likewise, WTO representatives participate in Commission sessions. Codex standards, guidelines and other recommendations are explicitly recognized under the WTO SPS Agreement and qualify as "international standards" under the *Technical Barriers to Trade* (TBT) Agreement. The SPS Agreement requires member governments to ensure measures imposed in the name of food safety that affect international trade are scientifically based on a risk assessment. The Agreement calls on WTO member countries to harmonize SPS measures based on international guidelines and recommendations developed by international organizations. In 1991, CODEX shifted its orientation from vertical commodity committees toward horizontal committees addressing food safety, and has been developing Risk Analysis principles.

The WTO is charged with settlement of trade disputes relating to food safety measures, drawing on the advice of scientific and technical experts: while inter-governmental organizations, in general, are not responsible for regulatory enforcement of food safety measures, this dispute settlement provision serves as a convenient enforcement mechanism.

Individual members are allowed to adopt SPS measures to achieve higher protection levels, if scientifically justified under risk assessment. When an importing country intends to alter its food safety requirements rendering them stricter than international standards, it is expected to: provide prior advanced notice and invite reaction from trading partners; and technically assist developing country exporters so as to adjust to the new requirements. Depending on its financial and trade predicament, a developing country can claim exemption from the obligations of the SPS agreement.

The SPS Committee, overseeing the SPS Agreement, meets three times a year, with decisions taken through consensus. Recent issues before the SPS Committee have been: BSE-related trade restrictions, the Belgian dioxin contamination, the EU's modification of Maximum Allowable Levels of aflatoxins in various foods as well as its restrictions on fish imports from certain cholera-affected African countries. Any international standards with proven trade impact may prompt the SPS Committee to request special examination by standard-setting bodies, for instance CODEX and OIE.

The **Technical Barriers to Trade** (TBT) **Agreement** applies to any food safety regulation falling outside the purview of the SPS Agreement, including nutritional standards, composition, grading, packaging and labelling. Labelling requirements on genetically modified food products and the Consumer's Right to Know, introduced by several WTO members to meet legitimate objectives, have been the subject of the TBT rather than the SPS Agreement. Just as in the SPS, members are to base their technical regulations on international standards. However, a government has the option of not basing its national requirements on such standards if deemed inappropriate to its particular objectives in terms of protecting the health of humans or of the environment.

The bulk of modern biotechnology research, both the processes and the products derived therefrom, is undertaken by industrialized country private sector firms, which protect Intellectual Property Rights (IPRs) through patents that extend beyond the first release. IPRs are critical for growth of the biotechnology industry, and lack of patent protection can limit access to the results of research originating elsewhere. Consequently, countries are required to honour the provisions of the WTO's **Trade Related Intellectual Property Services (TRIPs)** Agreement.

The WTO **Protocol on Biosafety** incorporates a precautionary approach. Under insufficient scientific information concerning potential adverse impact of a Living Modified Organism (LMO) on human health, let alone conservation and sustainable use of biodiversity, an importing member country is fully justified in taking steps to minimize such impact. The socioeconomic implications of this impact warranted collaborative research and information exchange.

4.6 Organization for Economic Cooperation and Development (OECD)

The main food safety entity within OECD is the *Task Force for the Safety of Novel Foods and Feeds*, concerned with the safety assessment of products of modern biotechnology, including genetically modified foods. By end-1990, efforts were underway to develop criteria for such safety assessment, leading to the concept of **substantial equivalence** (measuring safety against a suitable counterpart for comparison). Information used to determine substantial equivalence has been released on a crop-specific basis. There also exists a *Working Group for the Harmonization of Regulatory Oversight of Biotechnology*, concerned with safety assessment from an environmental angle. Its web site *BioTrack Online*, providing details of regulations as well as a database of field trials in OECD member countries and of products commercialized, serves an outreach function.

A *Working Group on Pesticides* seeks to improve the scientific basis for establishing Maximum Residue Levels (MRLs). It has been considering minimum standard data requirements for establishing MRLs, harmonized globally. The Working Group also, in February 2000, agreed to a joint OECD/FAO project to develop a global zoning system for pesticide residue field trials: sub-dividing the world into geographic zones within which pesticide residue behaviour would be comparable.

The OECD continues to perform major work in the following areas: biotechnology R & D, biotechnology statistics, research policy, scientific and technological infrastructure, and Intellectual Property Rights.

4.7 International Office of Epizootics (OIE)

The OIE complements the CAC in the area of animal diseases, for instance brucellosis, tuberculosis, Bovine Spongiform Encephalopathy (BSE). The SPS Agreement attaches equal importance to OIE recommendations just as to CODEX standards. OIE publishes the International Animal Health Code: animal health standards for international trade in animal products. A key function is to inform government veterinary services through an Early Warning System of the occurrence of epizootics, likely to endanger human health.

4.8 Cartagena Protocol

Since 1995, a Convention on Biological Diversity (CBD) Biosafety Protocol has been under negotiation, and has focused on the transboundary movement of Living Modified Organisms (LMOs). The Protocol was agreed upon in February 2000 in Nairobi, Kenya, and currently stands signed by 71 countries. Adoption into National Law by participating countries is expected in the coming years.

5. Food Safety Concerns in Technology Improvement Research

For the purpose of this note, technology improvement research at CGIAR Centres is categorized as production technology research and post-harvest technology research.

5.1 Production Technology Research

ICARDA: The rapid development of new virulent races of diseases and pests has placed growing emphasis on Integrated Pest Management (IPM). In this approach, host plant resistance is combined with other control options, including agronomic practices, biological control and limited strategic use of chemicals. Reduced infestation and lower chemical use both result in a safer final product. Research on the *sunn* pest of wheat identified egg parasitoids as a possible component in IPM to replace the present insecticide-based strategy.

Another example is the breakthrough achieved in breeding varieties of both bread wheat and durum wheat for resistance to *Hessian* fly, of benefit to the poorest farmers in Morocco. Cereal growers in North Africa have to safeguard food supplies from the ravages of this tiny fly. However, farmers can hardly justify using environmentally questionable and expensive insecticides. Meanwhile, good progress has been made in developing high-yielding and disease-resistant lentil lines in the major lentil-producing countries in WANA as well as South Asia.

IITA: Of the 10,000 species of fungi, at least 50 species are potentially harmful to the health of humans and animals. In particular, fungi of the genus *Aspergillus* produce a group of toxins called aflatoxins, that are linked to cancer, exacerbate *kwashiorkor* in children, are associated with inhibition of vitamin A absorption, and may slow down the rate of immune system development and child growth. Worse still, aflatoxins interact with hepatitis B to cause a very high risk of liver cancer in people who are exposed to both, and there are cases where people have died from acute aflatoxin poisoning. These strong poisons, which remain unaffected by cooking, can be passed on from animal feeds to livestock and on to humans who consume the livestock products, and even to babies from their mothers, either before they are born or as they are breast fed. IITA is developing a package of recommendations to reduce dangerous aflatoxins in stored maize.

In spite of an increase in maize cultivation in West Africa by 4 million hectares in a decade, agricultural technology is poor and internal food safety regulations are not necessarily enforced. Most maize is produced by small-scale farmers, with a yield of 1 to 2 t/ha. The harvest is usually stored on-farm throughout the dry season (4-7 months). Anything that damages grain, in the field or during storage, namely drought stress, birds, rodents, and insects, renders it vulnerable to fungal infection. Lower levels of toxin are associated with good crop husbandry including use of fertilizer, timely harvesting, sun drying, sorting out damaged cobs at harvest prior to storage, and controlling insects in the store. High toxin levels are attributed to the following: maize being cropped in the same field for several years;

when the harvest is left for more than 30 days to dry in the field; and when the harvest is stored in certain types of storage structures.

The aflatoxin problem, as many others, needs to be fixed at source, namely on the farm (pre-harvest) and post-harvest. It has been demonstrated that non-toxigenic strains of *Aspergillus flavus* can counteract toxin-producing strains in the environment by "competitive exclusion". Research so far has determined the characteristics of non-toxigenic strains, and limited success has been achieved in the US and Australia. Further field evaluations are required in Australia. More research on survival of the competitor strain in the soil and stability of the lack of toxin production is also necessary.

ICRISAT: The ACIAR's Peanut Stripe Virus (PStV) project 1986-90 identified the virus, developed means to detect it, and sponsored field screening of nearly 10,000 groundnut genotypes in Indonesia. Indonesian scientists were trained by ICRISAT scientists to identify PStV. Collaboration with the Queensland Agricultural Biotechnology Centre resulted in the production of a high quality antiserum against cloned coat protein of PStV.

Many crops of the semi-arid tropics (especially groundnut, sorghum and millets) are vulnerable to attack by a group of fungi *Aspergillus flavus* and *A. parasiticus* that are able to produce toxic metabolites, known as mycotoxins. Among various mycotoxins, aflatoxins and ochratoxin A occur in ICRISAT mandate crops as well as in associated crops: maize, chillies and wheat. They are harmful to human beings, poultry and livestock: aflatoxins are potent carcinogens and immunosuppressive agents while ochratoxin A is a nephrotoxin. Among several forms of aflatoxin, aflatoxin B_1 is more common in food and feed, and poses the risk of liver cancer.

Aflatoxin contamination of the seed by *A. flavus* can occur during pre-harvest, during harvest and drying in the field, and during transportation and storage. It is a major problem affecting exports and foreign exchange for the developing countries. Most developed countries apply a regulatory system whereby seed lots for import containing more than 20 ppb aflatoxin are banned. This system has seriously affected groundnut exports from developing countries to Europe: India was prevented from exporting groundnut for two years because of non-permissible levels of aflatoxins.

Research on an integrated management of aflatoxin contamination in groundnut has been pursued since April 1999, where biological control by competitive exclusion of *A. flavus* is a promising component. Biocontrol of aflatoxin contamination involves the use of competitive and antagonistic native micro-organisms that can reduce the populations of afla-toxigenic strains (*A. flavus*) present in the soil, and subsequently reduce infection to the developing pods and kernels of groundnut.

Fungi from the genus *Trichoderma*, isolated from natural habitats of the target pathogens, act as a mycoparasite: recognizing and attaching to the pathogenic fungus and excreting extracellular hydrolytic enzymes such as chitinase (chitin is one of the main cell wall constituents of many plant pathogenic fungi). Advantages of biocontrol include minimal disturbance to the ecosystem, non-applicability of gene technology, positive consumer perception, and the ease of technology transfer to other countries. Of note however is that aflatoxin may be minimized but not eliminated.

A main constraint to rainy season hybrid sorghum utilization is its grain mold (mycotoxin) content. A novel genotype is being developed in India through partnership between an Indian and a US plant-breeding company, with the finished hybrids subsequently produced and sold in the US. Joint public-private sector partnership lends itself to a potentially useful research area: identifying grain mold resistance through genetic markers.

ICRISAT has recently developed rapid and high throughput antibody-based screening assays for sensitive aflatoxin detection based on mutagenized germplasm from low-aflatoxin genotypes of *Arachis* species. It is hoped that molecular markers can accelerate an extensive breeding and back-crossing programme to identify and incorporate useful traits. Genes coding for aflatoxin-detoxifying enzymes (safe in food) have yet to be identified from fungal and bacterial sources. Another exploratory avenue is to influence the expression of plant genes involved in plant-fungus interactions so as to prevent aflatoxin production by the fungus.

Sorghum ergot, once found only in Asian and African countries, has a propensity for rapid, uncontrollable spread; it recently caught the sorghum industry of the American continents by surprise. Ergot causes crop losses by reducing the quantity and quality of seed, predisposing seeds to disease, and making harvesting and threshing difficult. Since the presence of ergot bodies increases disease transmission and toxicity risks, exports by sorghum-producing countries could become limited by food safety concerns. U.S. exports are near US$800 million at present; and the U.S. produces 40 percent of the world's seed, earning over US$435 million annually from its sales. About 90 percent of the sorghum area in South and Central America is planted with sorghum hybrids, with U.S.-based companies producing most of this seed. In pursuit of reducing losses from ergot to 1% of crop production, the community of agricultural researchers engaged in sorghum improvement programmes initiated a public awareness campaign about the disease, designing ergot management practices and regulatory policies governing international trade. Through ICRISAT's intervention, a methodology was designed to screen sorghum varieties for their resistance to ergot.

IRRI: The science of genomics is expected to revolutionize the breeding of future food crops. Rice, the staple grain for half the world's population, remains at the forefront of the latest research. In January 2001, the multinational agri-business corporation *Syngenta* announced completion of the sequencing of the rice genome (ordering of DNA sequences that encode 50,000 genes in the rice genome) and agreeing to freely make available the results for the benefit of poor farmers and consumers in the developing world. The genetic map identifies each gene on the 12 chromosomes that make up the rice genome. The next step is discovering the function of each gene. More than 100 genes conferring defence to the rice plant against pathogens have been found, available for selecting better disease-resistant rice varieties.

"*Bt* rice" is rice that has been modified, by means of biotechnology, with genes from *Bacillus thuringienis* (*Bt*); the gene induces the rice plant to produce toxins (proteins) against common insect pests, for instance stem borers. *Bt* is a species of bacteria, found in soil throughout much of the world. Maize, potato, and cotton plants containing *Bt* genes are now grown by farmers in several countries, maize covering an estimated 7 million ha as of 1998. Additional *Bt* crops, including *Bt* rice, could become available to farmers in the next few years. A potential benefit of the host plant resistance conferred by Bt rice is it reduces the use of costly chemical insecticides, given that rice farmers typically target 50 % of insecticide sprays for stem borers and leaf-feeding species, with concomitant negative impact on their health and on natural control of pests by spiders and beneficial insects. In 1995, Bt rice at IRRI was shown to be highly resistant to stem borers. IRRI research is underway to identify Bt toxins against stem borers, inserting genes for these toxins into rice and optimizing toxin production in the plant. A separate investigation centres on sustainable use of Bt rice: careful and strategic use of toxins to safeguard against evolution of insect resistance. The Bt research has been undertaken in parallel with achieving increased stem borer resistance through conventional breeding, yielding improved semi-dwarf rice varieties.

The International Network for Genetic Evaluation of Rice (INGER) is a unique partnership of rice scientists: about 1,000 from the national programmes of 95 rice-growing countries and from three CGIAR Centres (IRRI, WARDA and CIAT). The results of the INGER evaluation are shared with participating countries, and the best-performing rice varieties are freely distributed to cooperating countries, without copyright or patent considerations, and strictly adhering to safety and quarantine procedures.

CIP: In embracing genetic engineering as having a significant role in eliminating poverty and increasing food security through improved production/utilization of food crops, CIP will evaluate potential risks associated with application and deployment of genetically engineered organisms in terms of, among others, food safety, applying science-based criteria.

Integrated, locally appropriate disease management strategies are designed and tested, comprising, among others, development and deployment of resistant potato varieties, improved cultural practices, biological controls, insect traps, rational pesticide use, and farmers' capacity for prudent decision making. The very reduction in the need for pesticides, beyond the means of many poor farmers, by itself leads to safer food, let alone the environmental benefits. Pathologists are working on the Global Initiative on Late Blight (GILB), Bacterial Wilt of potato, and on several important viruses affecting potato, sweet potato, and Andean roots and tubers. CIP's largest research project is devoted to the integrated management of Late Blight, the world's most devastating crop disease and the greatest single constraint to potato production. Thus, to date, inclusion of health considerations in agroecosystem management has related solely to minimizing pesticide use.

As part of CIP's Natural Resources Management research, in *Carchi*, Ecuador, models of soil processes, pasture quality, dairy productivity, and crop growth are being linked with an economic "tradeoffs" model, quantifying the costs and benefits of different scenarios in terms of health, productivity, profitability, and environmental impact. Specific recommendations for land use management should emerge.

Concerning biosafety, CIP uses a variety of molecular biology and genetic techniques when these offer compelling advantages over conventional methods. Strict standards are maintained for protecting food safety, and for limiting the unwanted spread of pathogens and pests.

CIMMYT: The position of maize as the world's most widely grown cereal reflects its ability to adapt to a wide range of production environments. From Mexico to the Northern Andean region in South America, it is an important staple in rural areas. However, the use of technology together with improved varieties is limited. The world's industrialized economies have diversified the use of maize for animal feed and industrial use.

Most of the research and development in maize biotechnology is carried out by international private companies based in Europe and United States. Foreign genes have been randomly inserted into maize with the aim of: developing plants resistant to pests and diseases and thereby lowering farm-level production costs; and enhancing product quality through improving nutrient content and processing/storage characteristics.

At present, two types of transgenic maize have been commercially released, some of it in various “non-centres of origin” areas: 1) insect pest- resistant maize expressing delta-endotoxin from *Bacillus thuringiensis* (Bt); and 2) herbicide-resistant maize.

The insect resistance trait can be transferred simply by crossing one transgenic plant with normal plants. Bt corn has resulted in yield gains of up to 8%, on the basis of field trials conducted in the US as of 1993. The associated reduced use of pesticides translates directly into higher profits—between US$ 7-36 per ha for corn in the US, not to mention the long-term environmental benefits from the same, drawing the interest of ecologists.

A second well-known example of an input-reducing transgene is the gene that provides resistance to glyphosate herbicide. This gene has been used by Monsanto to develop the so-called *Roundup Ready* glyphosate-resistant variety of corn, which occupied an estimated 2 million ha in 1998. A single application of Monsanto’s Roundup herbicide effectively controls broadleaf weeds, reducing the need for multiple herbicide applications.

A separate research development has been: genetic engineering of anti-fungal proteins, such as chitinases and beta-1, 3-glucanases, so as to be expressed in the maize kernels, with the aim of preventing the growth of *Aspergillus flavus* and the associated production of aflatoxins.

While there may be no urgent need for nutritionally enhanced foods in most industrialized countries where the vast majority of consumers are able to meet minimum daily nutritional requirements, such enhancement could play a key role in alleviating the condition of the millions suffering from dietary deficiencies in many developing countries. Current research is focused on "second-generation" transgenic maize, among other crops, that represents improved nutritional and industrial qualities, for instance added vitamins and minerals. Such fortified products will also prove their worth in industrialized countries as a means of reducing consumption of unhealthy oils, proteins, and starches just as soybean and canola varieties have been engineered to produce healthier lower-fat oils.

5.2 Postharvest Technology Research

Food quality and safety are achieved through application of quality control throughout the food chain. Quality control starts at the farm level through use of good agricultural and veterinary practices, encompassing: seed selection; agricultural chemicals application; controlled use of irrigation water, animal feed and veterinary drugs.

The standard of postharvest operations (storage, drying, processing, packaging, transportation, marketing) has an equally important bearing on the quality and safety of the food item. Post-production operations account for more than 55% of the economic value of the agricultural sector in developing countries and up to 80% in developed countries. Yet, these receive relatively little public sector and developmental support. The CGIAR allocates less than 4% of its total funding to post-harvest development, and technical capacity within this sector remains very weak. It is noteworthy that Internal Rates of Return on post-harvest research can range from 20 to 50%, which compares favourably with those from production-based research, not considering the many non-monetary benefits in terms of improved diet, improved ecological practices, reduced drudgery and meal preparation time for resource-poor urban women, releasing time for other activities such as wage labour and education, each alleviating poverty in its own right. Post-harvest research thus promotes sustainable production, enhances income-earning opportunities for poor people, and has a significant bearing on poverty alleviation. At the same time, the urban poor are provided with time saving processed foods. The CGIAR has been addressing the efficacy and constraints in such operations, its most significant contribution being improvement of quality and storage capacity of food commodities.

CIAT has played a lead role in developing research strategies, focused on establishing and strengthening small-scale rural agro-enterprises that provide income opportunities for smallholders and landless labourers.

Current harvest and post-harvest research takes the following forms: product quality; harvest and storage; utilization and marketing (TAC, 1997).

Concerning **product quality**, the primary research aim of commodity centres with cereal crop mandate has been to refine the objectives of germplasm enhancement programmes so as to enable incorporation of desirable traits, such as fortification of certain nutritional components and resistance to pests, at all stages of the production-consumption chain, namely at harvest, during storage, during processing and at the point of human consumption. In root and tuber improvement, research has focused on presence of anti-nutritional factors; root shape and size; and dry matter content. In legumes, the biggest such constraint has been aflatoxin from fungi.

Alternatively, nutritive quality can be influenced through conventional means by way of modifying biochemical and physical characteristics of the product. To meet the market requirement for insect-free grain, Phosphine has been used in Australia and many other countries for several years. However, inappropriate fumigation practices have led to the development of insect resistance.

Harvest and primary product storage activities concern development of harvest mechanization and storage facilities for small producers; the integrated management of storage pests; germplasm enhancement for resistance to factors causing storage loss. IRRI has designed and field-tested prototype rice harvesting machines and grain drying systems. ICRISAT has a special project on pigeon pea improvement in Eastern and Southern Africa, with a sub-project on harvesting, storage and processing. IITA and CIRAD have jointly developed prototype mechanized root harvesting systems for cassava. Centres such as CIP, CIAT and IITA have engaged in on-farm research to develop loss-reducing crop storage systems.

The genetic manipulation of crop germplasm to generate resistance to pests and diseases during storage and processing is a major CGIAR research area. For instance, CIAT's bean programme includes resistance to *bruchids*.

Under **utilization and marketing**, opportunities for diversifying uses of the product based on demand are identified, and processing techniques and by-products investigated.

Transgenics for reduced post-harvest losses and enhanced shelf life, particularly in fruits and vegetables, have been developed for Asia.

The reduction of the cyanide potential in cassava exemplifies the significant impact of post-harvest research on food safety, of particular relevance to Africa where cassava toxicity has caused widespread suffering.

CIAT's work on cassava has demonstrated the value of a systematic approach to location-specific post-production constraints. Since the late 1980s, in collaboration with CIRAD, CIAT has placed emphasis on functional properties of cassava starch. Of equal note is CIAT's work on cyanide levels in cassava.

CIP has, likewise, been investigating potato and sweet potato processing.

IFPRI has been managing a project involving CIMMYT, CIAT and IRRI for enhancing micronutrient levels in cereals, legumes and root crops. Research outputs have been high-lysine maize and iron-rich rice.

Much dairy research has been focusing on improving the efficiency of established dairy farmers. ILCA has devoted significant attention to the development of milk production and processing techniques. The investment to develop and implement post-harvest technology could yield a higher return than increasing milk production.

ILCA, ICARDA and ICRISAT have examined the quality of by-products and their utilization as livestock feed. ICARDA and ICRISAT have specifically studied cereal and sorghum-based diets for sheep and poultry.

6. Policy Research and Food Safety

Much of the recently developed technology could well serve as important elements within a poverty alleviation strategy (Pinstrup-Andersen, 2000). Ensuring food safety is a key component of such a strategy, which demands more than just technology: an enabling policy environment is an essential pre-requisite.

It is clear that escalating food safety concerns in industrialized countries, governing production, processing, storage, transportation and international trade will subject developing country food commodity exports to new and more demanding food safety standards, both through changes in CODEX standards and through unilateral demands from importers. The risk persists of importers using the food safety question as a non-tariff barrier. Identifying what policies and institutions are required to fulfil the standards demanded in food production, processing and distribution is bound to be a key policy research area**.**

Food safety may well become a function of trade: only such trade may compel adherence to the requisite standards of identity and safety. The SPS Agreement requires parties to harmonize their national food safety standards with CODEX. Salient elements of policy research could be to determine the impact on purchasing power/food security of low-income producers and consumers, assuming: (1) higher food safety may well entail higher unit cost of production; and (2) acceptable risk level is subjective and consequently a discordance in food safety standard between poor and non-poor.

By 2025, it is projected that 43 % of the population of Least Developed Countries will be urbanized, with far-reaching implications for food supply and distribution, and food safety. The urban centres with greater population pressure and associated food safety threats may require special attention due to a knowledge gap vis-à-vis rural areas. A dynamic agro-processing industry produces backward linkages to farmers through increased demand for primary products from them and off-farm employment. Thus, there is a need for appropriate policies and institutions promoting such industry.

Equally important are policies providing incentives to farmers and communities to grow certain commodities and implement Good Practices such as soil fertility programmes. For instance, demand for cassava has not increased in step with the increased production potential. Hence, producers may receive erroneous signals against increasing their yields, only to lead to food shortage. In such a situation, safeguarding research attention would rest on diversification of end-uses: as food, animal feed and industrial raw material.

The utility value of any yield increase is critical to sustaining the increase. While the yields of certain sorghum hybrids may have increased, what increase has been registered in the “utilizable product” or in terms of benefits to resource-poor farmers or urban consumers is unclear.

ICRISAT, IITA and ILRI pursue technology training and extension with participation of both public and private sectors and users. ISNAR has been assisting Benin’s agricultural research system to incorporate post-harvest activities. Although innovative approaches to risk management along the entire life cycle of food commodities are available, application is lagging behind for want of suitable public and private institutions. Re-design and adaptation of such coping strategies warrants policy research. It is necessary to establish: functional infrastructures such as small-scale enterprises to apply and disseminate post-harvest technology; and grading rules and quality standards.

The food safety risks and opportunities associated with rapid biotechnology developments are also to be at the forefront of the policy research agenda for the next several years. In certain instances, the very lack of access by the poor to low-input, bio-engineered production techniques could result in more unsafe food and consequent food insecurity. At the same time, the possibly higher unit cost of production could weigh down on the benefits. Needed areas of policy research are: (1) health and environmental risks associated with food supply; (2) risk management in terms of more efficient coping strategies; (3) increasing water scarcity; and 4) deteriorating soil fertility. Knowledge derived from such policy research is what would guide *pro-poor* technology development.

A key item of policy research is Intellectual Property Rights restricting access of the rural poor to biotechnology as well as modalities of safeguarding such rights within developing countries to promote research by the indigenous private sector. An interesting investigation would be the impact of patents on farmers’ rights to traditional plant materials (the age-old debate before the International Commission on Plant Genetic Resources on Farmers’ Rights versus Plant Breeders’ Rights), diet diversity and nutritional well being.

Food safety is intricately tied to the availability and quality of water. Policies and institutions have to be identified that: provide secure water rights to users; decentralize and privatize water management; promote market-generated pricing of water use; create tradeable water rights backed up by incentives to conserve water; and impose realistic effluent and pollution charges. A key mandate of such institutions would be to arbitrate between conflicting uses of the same water resource.

As a country example, Indian government policy controls on food quality and safety have been largely inadequate to provide an acceptable level of consumer protection or facilitate trade and export of agricultural items: as of 1997, there were no monitoring or surveillance programmes concerning food quality, food contamination, food-borne illness or associated trade problems. Consequently, it could neither meet obligations nor realize the benefits of the WTO SPS and TBT Agreements.

7. Capacity Building for Food Safety

In the final analysis, the food-borne disease scenario is a reflection of the calibre and efficacy of technical personnel. They have to realistically evaluate the food-borne disease burden; assess the degree of benefit of specific research objectives to the poor; and set research priorities accordingly. The next steps are to: 1) frame legislation consistent with international instruments and with national needs and aspirations, covering, among others, risks and opportunities inherent to Genetically Improved (GI) foods; 2) set up proper regulatory bodies; and 3) put in place the requisite laboratory-based surveillance systems, tracking both outbreaks and sporadic incidences.

That strong food control systems are not sufficient to prevent food-borne diseases has been borne out by experience from industrialized countries: a comprehensive health and nutrition education programme incorporating food safety measures has to go hand-in-hand. Such a programme has to be culture-specific and involve diverse stakeholders, namely farmers, producers, food handlers, agro-industry personnel and consumers, starting from primary and secondary school children.

It is questionable whether the *safety of traded foods* argument could enable developing countries to improve food safety for their own people. Faced with daunting social problems that compete for diminishing resources and assuming that higher safety standards may well entail higher local food prices with detrimental impact on nourishment of the poor and their families, it seems unlikely that meeting export quality requirements would commensurately improve standards for the domestic food market. The poor's major concern relates to quantity rather than quality. The root of the problem may lie in insufficient technical knowledge.

However, even if there were a "knock-on" effect of trade on the domestic market safety standards, the average consumer would stand to gain little, since the foods in question are largely irrelevant due to cultural or economic barriers. On the contrary, the intolerance of developed country consumers of even minimal risk may well jeopardize the food security of the developing country poor. Besides, enforcement of domestic standards requires both political will and technical assistance.

Given heightened public interest in the increasing prominence of genetic engineering in the commercial production of foods, it is only imperative for every food industry professional to establish a minimal technology base to assess the new technology tried and tested elsewhere and suitably adapt it to local ecological and production conditions in conformity with national obligations for biosafety, release of GMOs and the sale of products derived from them. Biosafety refers to the safe use of all biological products and applications for human health, biodiversity and environmental sustainability in support of improved global food security. The WTO Protocol on Biosafety obliges parties to cooperate in the development and strengthening of human resources and institutional capacity for biosafety assessment through existing national and international organizations and the private sector. Local regulatory capacity has to be created within developing countries based on international guidelines for risk assessment and risk management (Pinstrup-Andersen *et al*., 2000).

At a higher level, creating indigenous biotechnology capacity requires skilled staff, well-equipped laboratories with proper working conditions, facilities for field-testing of Genetically Improved crops, so crucial for assessing health risk, and access to international networks and databases. The above has to be backed up by an adequate extension and training system.

In 1998, FAO and IAEA established the Training and Reference Centre for Food and Pesticide Control, aimed to strengthen, through technology transfer, the analytical capability of national food control laboratories in the areas of food contaminant monitoring and food safety/quality assurance. It also validates analytical methods to assess microbiological, mycotoxin, pesticide and toxic metal contamination of food.

8. Food Safety Issues Relevant to the CGIAR

It is clear that within the CGIAR System, there has been no set strategy to provide guidance on the topic and that work done to date has been largely incidental to the respective priority research thrusts of individual centres or, at best, of an *ad hoc* nature. The formulation of such a strategy would naturally enable drawing synergies from the currently isolated activities and prevent duplication.

It emerges that the key components for managing food safety are: efficient and rapid surveillance systems; prompt communication to consumers about the nature of risk; a credible and responsive regulatory system based on an on-farm food safety programme. Food safety is often a function of degree of development of the agricultural processing industry (including commodity storage and transport), which is rather under-developed in the poorer countries of Sub-Saharan Africa. It may be well worth tailoring food quality improvement technologies to**:** 1) the different agroecological zones and the associated growing environments; 2) various socioeconomic classes of producers/consumers; and 3) rural and urban settings.

Mountain areas, for instance, are particularly vulnerable to environmental degradation and certain health and social problems specific to physical and economic isolation. Understanding the complexity of highland systems is a critical first step toward designing integrated technology-policy solutions, ranging from water use and erosion control to product processing and marketing. A solid scientific base for decision-making calls for tools such as remote sensing, computer simulation modelling, and Geographic Information Systems.

The primary candidates for research should be the traditional crops relevant to small farmers and poor consumers in developing countries (banana, cassava, yam, sweet potato, rice, maize, wheat, millet) in their specific socioeconomic and cultural contexts. Possible key research areas are: reduced use of pesticides by way of Integrated Pest Management; hygienic practices along the lines of HACCP (one of the most efficient ways to minimize or eliminate food-based hazards) in the production and processing of both food crops and animal products; reducing mycotoxin risk for specific foods.

Given the CGIAR's focus on sustainable food security through poverty alleviation and natural resources protection and the growing rural and urban demand for cheap food, the potential income benefits from agriculture could be more fully realized by reducing post-harvest losses to maximize utilizable production for diversified end-uses. Each CGIAR Centre with mandate commodities has to identify constraints along the production-consumption continuum so as to prioritize "candidate" commodities for post-harvest research. Only then would food be affordable to different consumers along the rural-urban interface. However, such loss-minimizing postharvest strategies have to be married with a market-oriented strategy aimed at increasing benefits for producers, processors and consumers alike. The strategies have much at stake for women, who, within low-income rural households, play a dominant role in harvest and post-harvest activities. With increased emphasis on "utilizable" production, germplasm enhancement, likely to assume added importance, has to duly incorporate criteria such as suitability for processing and toxicity content. Furthermore, environmentally friendly food packaging materials using local raw materials would greatly enhance food protection and facilitate food trade. CGIAR could take up the task of assembling and coordinating interested groups to explore new processes for application to developing countries.

Cassava is one such "candidate" commodity, being a staple for a large number of low-income people. It is an ideal household-level food security crop thanks to its broad agroecological adaptability, drought tolerance and indeterminate harvest date.

The use of biotechnology leads to obvious and significant benefits in the form of increased production and productivity, improved food safety and quality by enhancing the durability of products during harvesting or shipping. Insect-resistant crops for poor farmers could be developed such as banana, cassava, yam, sweet potato, rice, maize, wheat, millet, reducing pesticide use and concomitantly enhancing food safety.

At the same time, biotechnology may present certain health and environmental risks. The transfer of genes from one species to another may cause the transfer of allergens, calling for: 1) testing prior to commercialization; and 2) due labelling of Genetically Improved foods with possible allergy risks. Other health risks are: toxicity, carcinogenicity, failure to remove antibiotic-resistant marker genes used in research prior to commercialization (Persley, 2000). The development of crops, of value to subsistence farmers, containing genes from the *Bacillus thuringiensis* (Bt) bacterium, which produces a natural pesticide, has still to be assessed due to the risks of: 1) development of resistance in pests; 2) adverse impact on beneficial insects; and 3) cross-pollination of wild and weedy plants with the new gene. Concerning the latter, certain seeds allow farmers the option of "turning off" genetic characteristics, preventing the spread of new traits (Pinstrup-Andersen and Cohen, 2000). Assessing environmental risk calls for establishing a baseline on the environment where new genes are introduced. Following a proper validation of these risks, the nature of international legislation can be determined. These risks associated with GM foods should be integrated into the general food safety regulations of a country.

Assuming this tool leads to safer foods for the poor, each country should decide how much of the technology should be developed nationally and how much imported and adapted (adaptive research). A good mix of the two can be synergistic and could reduce both the time and cost of developing biotechnologies and their products destined for the market. Decision making by developing countries to promote or block the import and commercialization of biotechnologies rests on five factors: Intellectual Property Rights (IPR), biosafety, trade policy, food safety policy, and public research investment policy. The CGIAR Centres have a vital role to play in all five areas, but perhaps by far the most important is IPR.

There is a glaring lack of relevance of private sector agricultural research in developing countries to the genuine needs of the poor. Protection of Intellectual Property (IP) provides the very economic incentive to the private sector to engage in *pro-poor* research; it governs plant variety protection, seed certification, and access to biodiversity. Enforceable IP protection encourages competition and leads to more products for farmers. More than 140 countries have already signed the TRIPs (Trade Related Intellectual Property Services) agreement of the WTO, intended, among others, to harmonize global seed-related IP issues.

With IP often precisely being the major constraint to technology transfer, the public sector could offer to buy exclusive rights to newly developed technology to make it available at little or no cost to small farmers. The CGIAR Centres could serve as an intermediary in thus helping convert social benefits to private gain.

The CIGAR Centres could also, serve as “honest-broker” institutions, to assist developing countries vis-à-vis the developed country private sector, the bearers of the technology. Perhaps the manner in which the first two Bt genes were made available to IRRI, as briefly explained below, could serve as a suitable model for CGIAR-private sector collaboration.

IRRI signed agreements with Novartis of Switzerland and *Plantech* of Japan, enabling IRRI to conduct research, for a fee, to improve the function of the Bt genes in rice and ultimately make freely available the products of the research to most developing countries. Following the research phase, a consortium including a CGIAR Centre opts to buy exclusive rights to the gene at a previously agreed price. The exchange of Bt genes between research institutions will likely grow in step with the further development of biosafety regulations and the conclusion of agreements on Intellectual Property Rights.

If a beneficiary country lacks the expertise to conduct its own risk assessment in the context of its own Biosafety Protocol, the CGIAR Centre could team up with national partners to develop appropriate strategies and methodologies, and assure confidence in a particular “bio-product”.

Concerning food safety in relation to animal products, researchable areas are: (1) technology modification/improvement at the grazing area level, at point of slaughter or during post-harvest operations, in the context of production system, for instance peri-urban animal production as compared to an extensive crop/livestock system; (2) food preservation technologies and suitable adaptation of HACCP principles to the developing country context, given their incompatibility with small and medium enterprises that characterize food processing and agri-business in such countries. For control and eradication of priority animal diseases (both those significant to trade and those influencing food security alone), applied research may be necessary in, among others, epidemiology and informatics, genomics and biotechnology, food safety and veterinary public health, and policy formulation.

Under epidemiology and informatics, an adequate national and regional-level surveillance and information system aims to seek out knowledge of the distribution and prevalence of key priority diseases, sound the alarm signals as and when necessary, and identify risk-based management measures to control the same. To arrive at such risk management measures, there is a significant need for application of GIS and modelling.

Genomics and biotechnology research develops diagnostic tools for priority diseases, for instance antigen/genome detection tests with a view to, among others, livestock population surveillance and trade certification. The end-objectives of the diagnostic techniques are rapidity, specificity, cost-effectiveness and versatility, enabling their application in minimally equipped laboratories, veterinary clinics and in the field. Improved vaccine development would entail better antigens as well as more efficient antigen delivery.

As for food safety and veterinary public health, low-cost preservation and processing techniques could reduce the incidence of food-borne bacterial pathogens.

Policy research concerning safety of animal products should aim at, among others, putting in place a community-based surveillance and vaccination system, with full cost-recovery. A separate avenue should attempt to quantify the real impact of animal disease in terms of refinement of new concepts such as Disability Adjusted Life Years (DALY) and Economic Value of Avoidable Losses (EVAL) (FAO, 2001). Concurrently, the return on potential investment in animal disease control should be investigated.

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