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The Role of Academe in Risk-based National Food Safety Programs for Developing Countries

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Food safety is integral to food security and sustainable development. The liberalization of trade in agriculture has given rise to the need for science-based food safety programs. The Codex Alimentarius, the standards and texts of which serve as the benchmark for food safety in the World Trade Organization, provides guidance in developing science-based measures to preempt or mitigate food safety risks. Within the Codex framework, risk analysis is the iterative and highly interactive process of ensuring that measures to assure the safety of food, i.e., standards, are scientifically and legally defensible. Despite a lack of resources to provide the ideal food safety infrastructure, institutions of higher learning in developing countries are in a unique position to respond to food safety challenges, as the specialized expertise needed for risk assessment, risk management and risk communication resides in these institutions. The tripartite function of teaching, research and extension of agricultural universities allows their resident experts to contribute to all aspects of risk analysis. Curricular programs in agriculture and food technology can accommodate a specialized course in food safety. With global concerns on food safety increasing, it is inevitable that food safety topics will be infused into a number of course offerings in related programs. University-based research can generate the data needed for robust risk assessment that adequately covers peculiarities in health status and vulnerabilities; such research can also provide information for designing appropriate risk management systems. Networking for the dissemination of information on food safety to all stakeholders and the provision of expert services will be key contributions to university extension programs on risk communication.

Despite the expertise that resides in agricultural universities, university-based experts still need to be familiarized with established approaches to ensuring food safety. Both disciplinary and integrated approaches are needed for academe to participate effectively in risk-based national food safety programs.

Key words: risk analysis, agricultural education, research, extension, transdisciplinary approaches

Introduction

The aim of the program on Agricultural Education for Sustainable Development (Ag-ESD) launched by the Agricultural and Forestry Research Center of the University of Tsukuba is to promote reform and improve "agricultural higher education, especially considering environmental problems from an international viewpoint". Sustainable development is inextricably linked to food security, which is achieved when the resources on which food production depends are used continuously with minimum damage to the benefit of the present and future generations (WHO, 2005). Integral to food security is food safety. The 1996 World Food Summit (FAO, 1998) defined food security as,

"all people, at all times, having physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life."

The commitment to food safety is also implicit in Principle 1 of the 1992 Rio Declaration on Environment and Development (United Nations, 1992), to wit,

"Human beings are at the centre of concerns for

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sustainable development.

They are entitled to a healthy and productive life in harmony with nature."

Biotic and abiotic environmental contaminants hazardous to human health can be transmitted through food, thereby threatening food security (WHO, 2003a). Food safety, as a component of sustainable development, contributes to public health, poverty reduction and the protection of the environment (WTO, 2001). Thus, there are compelling reasons for agricultural higher education to engage with issues of food safety within the Ag-ESD program.

Food safety is best defined in terms of risks to consumers' health; i.e., it is the assurance that food for both domestic and international markets, when used as intended, poses no unacceptable health risk to the final consumer. This definition is consistent with the risk-based framework of the Codex Alimentarius, the standards and texts of which serve as the World Trade Organization (WTO) benchmark for food safety (GATT-UR, 1994).

Having paved the way for low-income countries to trade their way out of poverty, agricultural trade liberalization brings to the fore the economic impact of food safety (Käfferstein, 2003). Sustainable development, however, requires that all countries take a holistic look at food safety and consider it both from trade and public health perspectives (WHO, 2003a). Because vulnerability to food safety risks is increased by poor diet, low income levels, and inadequate public infrastructure (Unnevehr *et al.,* 2003), developing countries need to address food safety concerns as a matter of high priority.

The Agreement on the Application of Sanitary and Phytosanitary (SPS) Measures or the SPS Agreement in the GATT-UR Final Act recognizes the sovereign right of Member States to adopt measures to protect human, animal and plant life and health, provided these measures are science- or risk-based (WTO, 1994). The process of risk analysis thus ensures that food safety regulations and related development programs are legally and scientifically defensible.

Due to limitations in human and material resources, developing countries lack the capacity to undertake risk analysis in support of national food safety programs (WHO, 2007). The Joint FAO/WHO Food Standards Programme implemented by the Codex Alimentarius Commission (CAC) provides for capacity-building in risk analysis in developing countries. Not only does this provision support the establishment of appropriate food safety measures under the SPS Agreement, it also facilitates the prioritization of scarce resources for food control (Boutrif, 2003).

Risk Analysis — A Science-based Approach to Food Safety

Risk to food safety is a function of the likelihood (probability) and severity of an adverse health outcome associated with a food-borne hazard. Risk analysis is a structured, iterative and consultative process to ensure that risk management measures, both voluntary and mandatory, have a sound scientific basis and adequately consider all other legitimate factors, including the needs of all stakeholders. Risk assessment, risk management and risk communication are the three distinct, but highly interactive components of risk analysis (CAC, 2006).

Risk assessment employs qualitative and quantitative methods to estimate the health risk associated with a specific food-borne hazard. Scientists commissioned on the basis of their specialization undertake hazard identification and characterization, exposure assessment and risk characterization, following established approaches and utilizing available data that have been subjected to peer review.

Risk management is the consultative process of weighing policy alternatives and options to manage food safety risks. Whereas risk assessors work within the boundaries of science, risk managers consider other factors relevant to the protection of consumers, as well as the possible socio-economic implications of risk management options. Utilizing the output of risk assessment, risk managers define the acceptable level of risk that underlies measures to ensure food safety and, in consultation with stakeholders, decide the best policy or management option. To safeguard its scientific integrity, risk assessment needs to be functionally separated from risk management. However, the interaction between risk assessors and risk managers provides for the iterative process needed to ensure that the most appropriate option is taken. Thus, effective risk communication by and between risk assessment

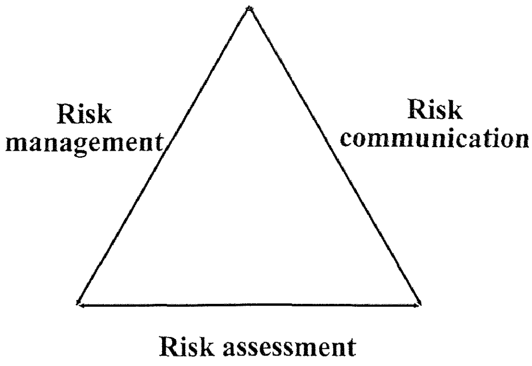

Fig. 1. The functionally distinct but highly interactive and iterative processes in risk analysis. Risk assessment provides the scientific basis for analysis. It paves the way for managing risks through appropriate measures that, if and when modified, might require a re-assessment of risks. Risk communication is needed throughout the process of risk analysis.

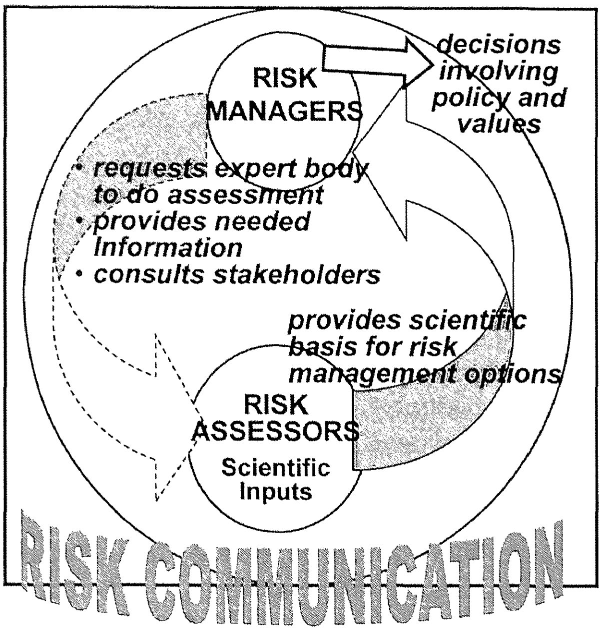

Fig. 2. The relationship between risk managers and risk assessors in risk analysis (adopted and modified from FAO/WHO, 2006).

bodies and risk management agencies is essential.

Risk communication, which pervades the entire process of risk analysis, consists of the interactive exchange of information among all stakeholders, including the explanation of risk assessment findings, the attendant uncertainties and the basis of risk management decisions. As risk analysis provides a rational approach to ensure a sound scientific basis for food safety measures, risk assessment might be considered the base of the process (Fig. 1; Lizada, 2006). The risk analysis cycle begins and ends with risk management in response to the need to pre-empt or mitigate the adverse health effects of food-borne hazards (Fig. 2).

Risk Analysis in the Setting of Codex Standards

The Codex Alimentarius is a "collection of internationally adopted food standards presented in a uniform manner" that "aim at protecting consumers' health and ensuring fair practices in the food trade" (FAO, 2007). The health and safety provisions of the standards and texts of the Codex Alimentarius are based on risk analysis.

Within the Codex framework, risk assessment is principally undertaken by the Joint FAO/WHO expert bodies, i.e., the Joint FAO/WHO Expert Committee on Food Additives (JECFA), the Joint FAO/WHO Meeting on Pesticide Residues (JMPR), and the Joint FAO/WHO Meetings on Microbiological Risk Assessment (JEMRA). The output of the meetings of expert bodies and consultations can be used when a country lacks the infrastructure to support risk assessment, as might be the case for developing countries. However, developing countries need to provide data for consideration in the deliberations of these expert bodies, so that the unique domestic situation of the country is adequately considered. The Codex statutory bodies, i.e., the Codex Alimentarius Commission and the Codex Executive Committee, and subsidiary bodies (Codex Committees) function as risk management bodies, considering expert meeting reports in deliberating on the health and safety aspects of standards being elaborated. Codex bodies involved in either risk assessment or risk management undertake risk communication, involving all stakeholders. The FAO/WHO Joint Food Standards Program encourages the greater involvement of developing countries in risk management through their active participation in the meetings of the Codex Alimentarius Commission and Codex committees.

The Roles of the Tripartite Functions of Academe in Risk Analysis

Agricultural education prepares future generations to meet the global challenges of food security (Mulder, 2009). One such challenge is building and sustaining capacity for developing and implementing risk-based food safety programs. With their tripartite function, agricultural universities are in a unique position to respond to this challenge. Together with other institutions of higher learning they play a pivotal role in agricultural knowledge systems, which are vital to food security and environmental sustainability (World Bank, 1999). Agricultural education contributes to information systems, which provide guidance to farmers, traders and consumers on food safety.

The United States National Academy of Sciences (NAS) identified food safety along with the expanding global population, global resource constraints and environmental quality as a part of the contemporary landscape to which teaching, research and extension in universities will have to adapt in order to contribute to the productivity and sustainability of agriculture (NAS, 1997). Subsequently, the Agricultural Research, Extension, and Education Reform Act of 1998 provided competitive grants under the National Integrated Food Safety Initiative to support multi-state, multi-institutional, multidisciplinary, and multifunctional research, extension, and (formal) education activities of faculty in all four-year accredited colleges and universities (USDA, 2009). The US Department of Agriculture (USDA) Agricultural Research Service has also partnered with 20 universities to form the National Alliance for Food Safety and Security to cover the science of safe food through food safety research, education and outreach. The alliance works with other government agencies, industry and consumer groups to advance the safety of the food system (NAFSS, 2009). Similar partnerships have been actively contributing to food safety programs in Canada and the European Union.

Despite resource constraints, universities in developing countries can respond in a similar fashion and endeavor to contribute to food safety systems. The University of the Philippines Los Baños (UPLB), now a comprehensive university, was started as a campus specializing in agriculture and forestry nearly 100 years ago. Over the years, UPLB has addressed the education and technical needs in agriculture in the Philippines and the Southeast Asian region, serving as the host institution for the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA). Noting UPLB's historical strengths, a recently conducted external review concluded that UPLB can take a lead role in addressing issues related to food security, highlighting the support that it can give to food quality and safety through the supply chain (McArthur *et al.,* 2008). More specifically the external review identified food security/safety as a niche UPLB can create through curricular and research and development programs. Over the years, UPLB has partnered with government agencies to address food safety considerations in such areas as cultural and pest management, food processing and quality monitoring, and animal health.

Teaching

Being science-based, risk assessment requires inputs from various academic disciplines, including microbiology, chemistry, toxicology, food science, physiology, nutrition, pathology and epidemiology (NRC, 2009). Institutions of higher learning have equipped graduates with the basic capacity for risk assessment, but academic programs specifically designed to address the capacity needs for food safety risk analysis are a relatively recent development, even in developed countries. The University of Pretoria in South Africa offers the course "Risk Assessment and Sanitary and Phytosanitary Issues", which focuses on pest risk analysis in relation to plant quarantine, but includes food safety in its course content (University of Pretoria, 2008a). Pest risk management options include phytosanitary requirements, which might also entail food safety considerations.

Import risk analysis (IRA), which covers pests and pathogens with potentially adverse effects on the health of economically important plants and animals, is a usually contentious area in which developing countries need to build capacity. Food safety is of a greater concern in IRA covering zoonotic diseases in animals or animal products, e.g., bovine spongiform encephalopathy (also known as BSE or mad cow disease). The Food and Agriculture Organization (FAO) identifies IRA as a distinct scientific discipline (FAO, 2003) requiring multi-disciplinary inputs. The lack of capacity in IRA does not only add unnecessary costs to food exports; it also limits marketing opportunities for these products. Thus, capacity in IRA is essential, and IRA case studies would be an appropriate component of plant protection and animal health courses.

Familiarizing students who are majoring in statistics or actuarial science and such related fields as mathematics, business or economics with food safety issues should produce graduates capable of contributing to capacity building in the application of risk assessment tools to food. Globally, there is a need for experts knowledgeable in the fundamental science, but with a comprehensive appreciation of risk analysis, as this process finds application in a wide range of risk-related concerns (Gordon Research Conferences, 2003; APEC, 2002).

Opportunities for the infusion of risk analysis in existing courses abound in agricultural and food programs. However, a graduate-level course on risk analysis might be considered for institution in curricular programs in food science and technology. The curricular programs of the University of Pretoria provide a good illustration of infusing risk analysis into existing courses (University of Pretoria, 2008b). The undergraduate program leading to a Bachelor of Science (B.Sc.) in Food Science is designed to prepare the student for a scientific career in the food industry. The B.Sc. (Agric.) Food Science and Technology program, on the other hand, provides graduates with the skills to understand and apply concepts related to sustainable food quality, safety and security, and is designed to equip graduates with specialized knowledge for application to production and manufacturing processes. All the courses in both programs can incorporate topics related to risk analysis in food, at the very least by way of illustrating principles or citing examples. In contrast, a more extensive coverage of risk analysis would be appropriate for the courses on Food Legislation and Food Safety and Quality Assurance, which are included in the applied food science courses of the B.Sc. (Agric.) Food Science and Technology program. Notably, both programs include a basic science course in nutrition that could cover topics such as GEMS/Food regional diets (WHO, 2003b) and assessment of exposure to food contaminants may be covered more specifically in relation to dietary patterns.

In the Philippines the policy and standards for the Bachelor of Science Food Technology (BSFT) curriculum issued by the Commission on Higher Education (CHED, 2006) require a 3-unit (i.e., 3 hours of lectures per week) professional course on Food Safety (UPLB, 2009a). Prior to this requirement, the BSFT curriculum in UPLB included a number of courses into which food safety topics were or may have been infused, including the required courses in crop and animal science (UPLB, 2009b). Provision of a "farm-to-fork" perspective is essential to curricular offerings in food safety. Herein lies the distinct advantage of food science and technology programs based in universities with a strong agricultural program.

The expertise needed to develop and promote good agricultural practices that are risk-based and preempt food safety risks on the farm is best developed in curricular programs for students majoring in agriculture and specializing in production or animal husbandry and pest management. Interactions between these and food technology programs will undoubtedly contribute to a holistic approach toward safeguarding food safety through the production-marketing continuum.

The food safety-related curricular programs of the University of the Philippines (UP) System present an excellent opportunity for complementing one another (UP, 2009). Production systems are covered by UPLB and UP Visayas, with the latter specializing in fisheries. A good geographic coverage of food processing is provided by four campuses (Diliman, Los Baños, Visayas and Mindanao) offering programs leading to a BS in Food Technology. The College of Public Health offers an elective course in food safety for students specializing in nutrition, providing a public health perspective on food safety. As food safety risk management involves both voluntary and mandatory measures, the latter points to the possible need to translate the outputs of risk analysis into legal issuances, and to also ensure that regulatory measures are risk-based and legally defensible.

Competence in food safety law is indispensable in an environment where the liberalization of trade can have profound effects on the agriculture sector. The United States created the National Agricultural Law Center based at the University of Arkansas and expanded its scope to cover food law (www.nationalaglawcenter.org/about/). Curricular offerings in food laws, including food safety, in law schools would certainly enhance food safety infrastructures. Orienting law students in food and food safety law would help ensure the availability of competent legal expertise, the lack of which puts developing countries at a distinct disadvantage in trade disputes or WTO negotiations (Van der Borght, 1999).

Research

The number of scholarly publications on the physical, chemical and microbiological hazards in food reflects the intensity of research and, therefore, the availability of data for use in hazard identification and characterization. Risk assessment makes use of available data, but where data are lacking, research needs are identified and risk characterizations are refined as the required data become available. In Codex deliberations, developing countries are encouraged to submit data that would allow better consideration of the peculiarities of their populations and environments that might impact on risk assessment. In setting the maximum residue levels for pesticides, risk assessment takes into account the metabolism and degradation of pesticides; pre-harvest factors such as climate, soil types and pest pressure; and post-harvest factors such as storage, processing and distribution conditions.

Data on consumption patterns are needed to validate exposure assessments based on dietary clusters in the GEMS/Food regional diets. Determining the total dietary exposure to a specific contaminant based on consumption patterns constitutes the most important step in evaluating whether a proposed maximum level for the contaminant (e. g. pesticide or veterinary drug residues) provides an adequate level of protection for most consumers (CAC, 2001). The lack of reliable global data on consumption patterns is still a problem and constitutes a key challenge to food safety research programs in developing countries (Chen, 2004).

Of special concern to most developing countries are the dietary patterns and consequent nutritional status of farming families (FAO, 2004) because of the effect these have on their vulnerability to food-borne hazards. In rice-producing countries, for example, smallholder rice farmers are at greater risk from rice-borne hazards, both because of their poor nutritional status and their relatively high consumption of this staple food (Lizada, 2006). Infants and children are inherently more vulnerable to food safety risks.

The preliminary evidence of an interaction between chronic exposure to aflatoxin and nutritional and health status warrants further investigation, particularly in developing countries (Strosnider *et al.,* 2006).

A number of developments emphasize the need to generate food safety-related data in a timely fashion to reassess risks and review risk management options:

1. Climate change, which is expected to increase food safety risks, particularly among the vulnerable (Balbus and Malina, 2009);
2. An increase in subpopulations rendered more vulnerable as a consequence of being immunocompromised (Abong'o *et al.,* 2008) and having poor nutritional status;
3. Emerging technologies e.g., the use of modified-atmosphere packaging with elevated levels of carbon dioxide, which have been found to increase type E botulinum neurotoxin gene expression and neurotoxin formation (Artin *et al.,* 2008);
4. Novel foods that have no conventional counterparts and are, therefore, deemed to have no substantial equivalence with a known food product (SCF, 2002); and
5. New information demonstrating adverse food combinations or food-drug interactions, such as the disulfiram-ethanol-like effect of alcohol ingestion after durian consumption (Maninang *et al.,* 2009).

Research in integrated pest management will need to be intensified to mitigate the food safety risks associated with increased pest pressures arising from global warming (IITA, 2008). Cognizant of the projected effects of climate change and the vulnerability of developing countries in Africa, the International Development and Research Council of Canada has indicated that it is preparing to fund research and capacity-building activities related to food and nutritional security or food safety resulting from climate change and variability in East and Southern Africa (IDRC, 2009).

Results from research into food-drug interactions have implications on "intended use" in the definition of food safety. This field of research can lead to the formulation of precautions on food-drug/alcohol combinations, because foods considered beneficial to health might actually elicit adverse effects. The bioactive constituents in the disulfiram-ethanol reaction appear to be sulfur-containing phytochemicals, a number of which are formed or increase in response to stress (Rausch and Wachter, 2005). Research into such reactions provides insights into how the production and post-harvest environment might be managed to control the associated risks. Research needs to go beyond the more dramatic acute effects and include chronic effects, both of which are considered in risk assessment.

The study on the durian-alcohol interaction referred to above provides an example of the opportunities for collaboration that exist between developed and developing (North-South) countries on food safety research. The University of Tsukuba provided laboratory support for the senior author's thesis, a requirement for his MS Food Science program at the University of the Philippines Diliman. The benefits of such partnerships to support a risk-based approach to food safety cannot be overemphasized. North-South cooperative endeavors need to be cognizant of (1) the need for developing countries to make crucial decisions in the process of achieving their goals in sustainable agriculture; and (2) the potential to use the indigenous knowledge of local experts to properly assess the potential environmental and socio-economic benefits and negative impacts of technologies that might be developed and adopted (USDA, 2003). North-South partnerships that fully incorporate these components will strengthen food safety regulatory systems through the sharing of food safety risk data and scientific expertise (Hogg *et al.*, 2008).

The Consultative Group on International Agricultural Research (CGIAR) has identified research on trade, markets, and food safety as a major new research emphasis in the System Priorities for CGIAR Research, 2005-2015 (CGIAR, 2005). The CGIAR considers that the involvement of national agricultural research systems (NARS) in research consortia is of strategic importance to ensure these priorities are implemented, because they can enhance opportunities for South-South interactions and regional spillovers. Universities are generally recognized as an integral component of NARS (FAO, 1991).

Cogent arguments to support public investments in food safety require robust economic analyses, which, in turn, require epidemiological data, health costs, loss of productivity and related data. University-based agricultural researchers might not be in a position to provide these data and need to forge partnerships with government health units or agencies.

Extension

The multi-faceted involvement of universities in teaching and research related to food safety programs creates numerous and varied opportunities for extension. These opportunities might include:

1. offering non-formal education, including training programs in food safety;
2. providing expert services and guidance to government and industry for risk assessment and risk management, including food safety emergency preparedness;
3. providing information services for all stakeholders following the principles of risk communication—and thereby ensuring the availability and accessibility of accurate, reliable and easily understood information—for consumer education and rapid alerts; and
4. conducting action-research projects.

ISO 22000: 2005, which specifies the requirements for a food safety management system (Færgemand and Jespersen, 2004), emphasizes a risk-based approach in Hazard Analysis and Critical Control Points (HACCP). It requires an adequate appreciation of the process and outputs of risk analysis in the food industry. Larger commercial food manufacturers procure technical assistance to pursue certification under this scheme. In contrast, micro, small and medium enterprises (SMEs) engaged in food processing in developing countries find difficulty in complying even with the minimum regulatory requirements of good manufacturing practices (GMP). GMP and sanitation standard operating procedures or SSOPs are prerequisites to HACCP.

University extension programs need to address the specific needs of micro-enterprises and SMEs, and should adopt creative approaches that will enable these enterprises to comply with minimum food safety requirements while simultaneously protecting the consumers of their products. The WHO has acknowledged the unique needs of less-developed businesses in the food industry and has puiblished a guide aimed at assisting them (WHO, 1999).

Another concern in developing countries is the sale of food through the informal sector, the means by which lower-income groups source affordable food. The challenge to developing countries is how food safety standards can be imposed without driving the informal sector underground. University-based extension programs can provide technical assistance to government, more specifically local government, and to the private sector to address the issues related to the informal sector. According to Unnevehr and Hirschhorn (2009), there are a number of ways of feasibly contributing to improvements in food safety in the informal sector, some of which involve extension programs:

1. identifying specific sanitation investments that can improve hygiene during food processing and handling;
2. ranking food safety risks in order of importance and ease of control;
3. formulating cost-effective risk management measures to address priority risks;
4. training of trainers in basic hygiene;
5. creation of networks for the dissemination of food safety information; and
6. adoption of appropriate extension methods to guide food control officers, other extension workers, consumers and food handlers in the informal sector.

Transdisciplinary Approaches and Academe's Contribution to National Food Safety Programs

The multifaceted nature of food safety requires a seamless interface among stakeholders (Fig. 3), and university-based experts can make significant contributions towards ensuring that the interface is supported by risk-based knowledge. However, a holistic approach to food safety cannot be achieved

Fig. 3. Academe as a key partner in ensuring food safety for all (adopted and modified from WHO, 1996).

within the confines of the disciplinary specializations along which most universities, including those in agriculture, are structured. Universities need novel approaches to curricular, research and extension programs to facilitate information exchange and understanding between and among disciplines.

A transdisciplinary approach has been described by Weismann *et al.* (2008) as one that:

"...trans-gresses boundaries between scientific disciplines and between science and other societal fields and includes deliberation about facts, practices and values."

Transdisciplinarity (Hammer and Soderqvist, 2001) might be an appropriate approach for universities to respond more effectively and in a timely fashion to food safety challenges. The disciplinary boundaries in agricultural education will remain, and will be needed to ensure the continued availability of specialized competencies for undertaking studies and providing information for risk assessments. However, a transdisciplinary orientation in the tripartite function of agricultural universities will help meet the multi-dimensional requirements of risk management and risk communication in food safety. Fischer *et al.* (2005) noted that a transdisciplinary approach would be appropriate to food safety risk analysis, and Francis *et al.* (2008) encouraged the adoption of transdisciplinary approaches to connect scientists and consumers with the origins of food to highlight the importance of the natural environment.

The Codex Trust Fund was established in 2003 to help enhance the level and effectiveness of the participation of developing countries in Codex standards development. The inclusion of university-based experts in the capacity-building programs supported by the Trust Fund should help familiarize academics in developing countries with the principles and practices of risk analysis and enable them to make significant contributions to national food safety programs.

Conclusion

The academe in developing countries, particularly agricultural universities, can make invaluable contributions to risk-based food safety programs through the tripartite function of teaching, research and extension. The diverse expertise required and the complexity of food safety systems call for a good balance of traditional and novel approaches to achieve the goals and sustainability of food safety programs.

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