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BIG Questions Small Worlds

Following Diverse Vistas

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INTRODUCTION

More than three hundred years ago, van Leeuwenhoek was the first person to look into the mysterious small world inhabited by a thousand different kinds of tiny beings, some ferocious and deadly, some friendly and useful to their big brothers, the human species, and many more important to mankind than any government, continent or island. Microbe hunters (microbiologists) are the men and women who take on the quest to explore this unseen world of invisible and fascinating strangers in order to acquire and apply knowledge about microbes and how they affect our lives.

We are faced with the challenge of understanding the structure and function of man and microbe systems, the component parts which interact with each other in complex and diffuse ways at different scales of space and time. The biosafety of his food supply has been a major concern of man since ancient times. For example, much of ancient Hebrew dietary laws has its origins in the minimization of risk associated with the consumption of certain foods, based on the knowledge and understanding of the people who drew up those laws. Today we are able to develop a biologically meaningful understanding of microorganisms and to differentiate between bad (pathogenic) and good (useful) "bugs".

There are three main ways in which pathogenic microbes can enter the food supply and cause illnesses. Animals harbor pathogenic microbes, making meats, poultry, eggs, and milk the most often implicated vehicles. Pathogenic microbes, which are introduced into the environment, possibly through manure and litter, may persist and contaminate fruits and vegetables on the farm. Cross-contamination in the food service environment or the home, often between raw poultry and ready-to-eat (RTE) products, such as raw vegetables, can also cause food borne infections. However, it is impossible, to create a completely risk-free food supply. While

food manufacturers and distributors employ the necessary control measures to ensure the safety of food until it reaches the consumer, all food handlers and consumers have the responsibility, upon purchase of the food, to continue to maintain these control measures until consumption.

New tools and techniques are becoming available that allow us to use a vast array of information sources in the control of food borne pathogenic microbes (biosafety), such as the microbiological risk assessment (MRA), and also to explore these invisible creatures for the endless chemical transformations they perform (bioenergy), for example, to generate green energy from renewable biomass such as biofuels.

MICROBIAL FOOD BIOSAFETY: MICROBIOLOGICAL RISK ASSESSMENT (MRA)

The title of the first part of my presentation suggests change, and hopefully progress, in our thinking about food biosafety. Foodstuffs may act as vehicles whereby living food poisoning bacteria gain access to the human body, due in part to the consumption of inadequately cooked food or, more usually by cross-contamination at the retail outlet or in the kitchen, from raw foods to precooked or fresh foods that will be consumed without further cooking. The continually increasing international trade in food means that we would be unwise totally to ignore bacterial food borne infection as they are certainly of considerable concern to commercial organizations engaged in international trade.

Outbreaks of infectious diseases associated with food captured the attention of many national and international regulatory agencies, non-governmental organizations and also the mass media. The term biosafety is a buzz word coined in the 1970s concerned with the safety of the public and the environment from exposure to biological

agents such as microorganisms. One particular area of interest in public health is the safety of foods, i.e. food free from pathogens and other agents inimical to human health. It has become a trend that public discussions on food safety topics have often developed into ethical or political controversies, obstructing a scientific approach to the evaluation and management of biosafety issues.

The most urgent issues in biosafety are currently connected to the emergence of new food borne diseases or the resurgences of diseases, which for some time seemed to be under control, but have now reemerged. Preventive strategies for the control of new and remerging food borne pathogens include the strengthening of local, state, and federal public health infrastructures to support surveillance and implementation of prevention and control programs.

The strategy is based upon the premise that it is far less costly, both in terms of human suffering and economics, to anticipate and prevent food borne infections rather than to react with expensive treatments or containment measures to unanticipated food biosafety crises such as the sudden ban on seafood exports from Malaysia to European Union member countries in June 2008. We are fortunate to be able to work towards this food biosafety in perhaps the most interesting times in history with the occurrence of two of the most significant changes in human history. I am speaking of the rapid progress in biological sciences that has led to the genetic engineering revolution, and the invention and development of computer technology that has led to the revolution in information handling and management. These revolutionary changes will help us to create better foods by providing us with more rapid and accurate testing procedures for the detection and quantification of microorganisms and their toxins, and assisting us in the collection and management of the data necessary in modern food biosafety systems.

Our ability to deliver safer foods will depend in large part on our ability to communicate our intentions to many audiences. To improve food biosafety in these times, we need not only the collaboration of food processors, microbiologists, and researchers, to understand and control identified food borne hazards; but also the collaboration of physicians and epidemiologists to detect and identify emerging food borne hazards. Today we master microbial food biosafety along the farm to table chain with different good practices which are the consequence of human culture, lifestyle and history (Figure 1).

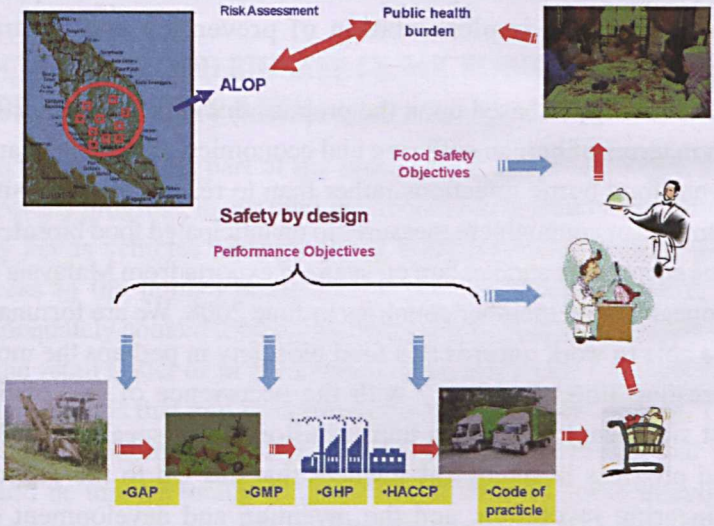

Figure 1 Good practices for microbial food biosafety along the farm to table chain

On the theme of biosafety, it is important to recognize that Malaysia continues to face serious quantifiable and apparently deteriorating situations with regard to microbiological contamination

of foods. We have reported on the various foodborne pathogens detected in different types of foods retailed in wet markets and supermarkets in Malaysia (Rusul *et al.*, 1996; Son *et al.*, 1996; Son *et al.*, 1997a, Son *et al.*, 1997b; Son *et al.*, 1998a; Son *et al.*, 1998b; Son *et al.*, 1998c; Son *et al.*, 1998d; Son *et al.*, 1998e; Son *et al.*, 1999a; Son *et al.*, 1999b; Son *et al.*, 2000a; Son *et al.*, 2000b; Son *et al.*, 2000c; Son *et al.*, 2001a; 2001b; 2001c; Son *et al.*, 2002a; 2002b; Lesley *et al.*, 2003; Noor Zaleha *et al.*, 2003; Son *et al.*, 2003; Chen *et al.*, 2004; Nasreldin *et al.*, 2004; Nimita *et al.*, 2004; Koitabashi *et al.*, 2006; Jurin *et al.*, 2006; Haryani *et al.*, 2007; Marlina *et al.*, 2007; Robin et al., 2007; Chai *et al.*, 2007; Yoke-Kqueen *et al.*, 2007; Chai *et al.*, 2008a; Chai *et al.*, in press). The need here is primarily for education on the rules of hygiene. It is unhappily true that the vast majority of food borne infection incidents arise as a result of inappropriate handling of foods in the home kitchen or food preparation areas, as the results of a recent seven-country survey (United Kingdom, United States, Germany, South Africa, Saudi Arabia, India and Malaysia) conducted by the Hygiene Council (a global panel of experts in microbiology, virology, infectious diseases, immunology and public health) shows that Malaysian kitchens were more bacteria-infested than bathrooms and overall Malaysian homes were found to be among the dirtiest among the countries studied, right after India (a paradox in having first world infrastructure but third world hygiene and sanitation standards). Incidences of food poisoning happen sporadically in Malaysia all year round, in some cases death occurs. In addition, European Union member countries enforced a blanket ban on import of seafood from Malaysia, though in response Malaysia temporarily halted the export of seafood to the EU countries to protect the industry.

Conventional testing of food for microbiological hazards has, until recently, consisted almost entirely of carrying out

microbiological tests on finished products. In the food industry, this approach of post production testing is essentially negative. What is needed is a thorough understanding of the factors influencing the growth or persistence of dangerous pathogens in a food product and modification of the recipe or the manufacturing process in such a way as to eliminate the possibility of the final product carrying living pathogens. This is the rationale behind the Hazard Analysis Critical Control Point (HACCP) concept. In this approach the elimination of hazards as opposed to the detection of hygiene failure is becoming the norm in food manufacturing industries. However, hazards cannot be completely eliminated or prevented with our present state of knowledge and the present structure of the food industry. In reality, HACCP is an industrial tool to produce/prepare a safe and specific product manufactured in a specific location/ production-line whereas risk analysis/MRA is a support tool for governments in the management of risks of a specific product or group of related products, manufactured by different companies in a multitude of locations and production lines. Hence, MRA is not needed in HACCP and vice versa but they can be mutually beneficial.

Malaysia acknowledges the importance of Risk Analysis as the basis for all food safety management, development of food safety standards and managing risks associated with food hazards, complementing the numerous food safety initiatives that are currently being implemented.

RISK ANALYSIS

During the past decade, there has been a significant paradigm shift in how food biosafety standards and guidance are developed for foods in international trade as reflected by the emergence of new tools in risk analysis (i.e., risk assessment, risk management and

risk communication) to provide a more direct link between the stringency required in food safety systems and the level of public health protection achieved (Figure 2). Adopting concepts such as Appropriate Level of Protection, Food Safety Objectives and Performance Objectives and the use of risk assessment techniques provide the means for linking public health goals to more traditional criteria such as microbiological criteria, processing criteria and product criteria (Figure 3). In risk analysis (Figure 2), the functional separation of risk assessment and risk management ensures that issues are addressed in a transparent manner with a scientific approach in estimating a risk and understanding the factors that influence it. Risk assessment starts with a statement of purpose or problem formulation and the process includes four elements: hazard identification, exposure assessment, hazard characterization and risk characterization. Overall the interaction between the risk assessment, risk management and risk communication and all the stakeholders are presented in Figure 4.

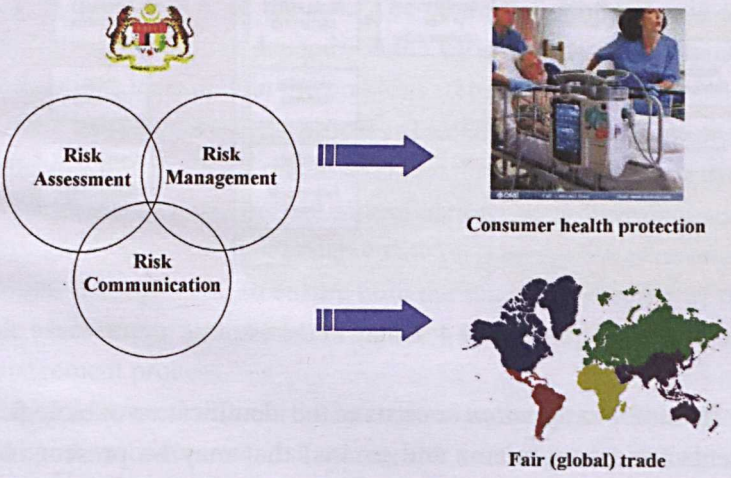

Figure 2 Risk analysis concepts

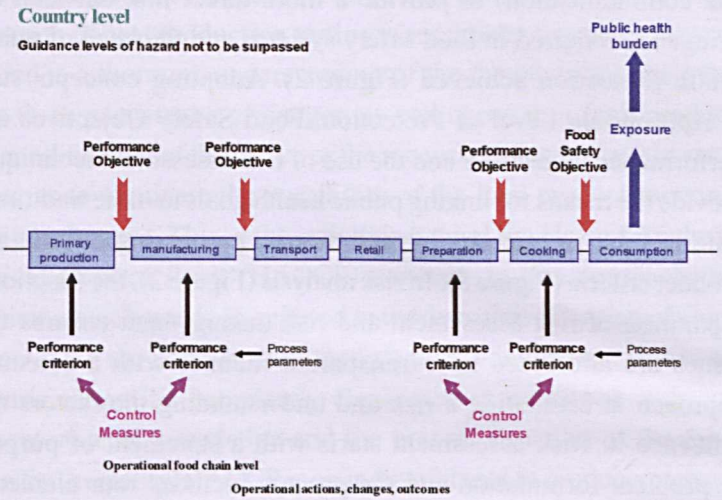

Figure 3 Operational actions, changes and outcomes in risk assessment

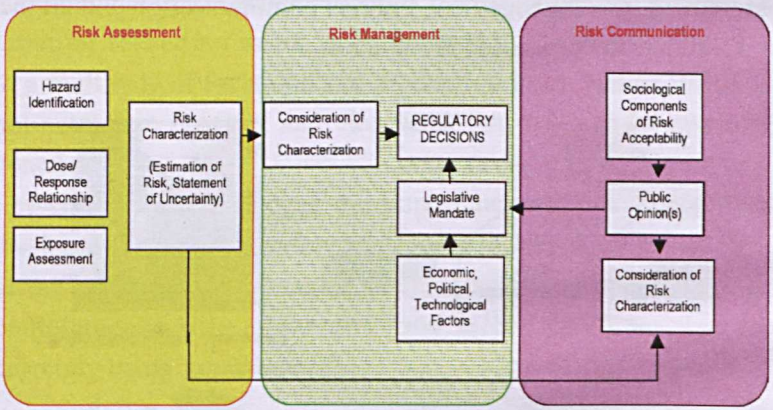

Figure 4 Trinity of risk issues

Hazard identification consists of the identification of biological agents (microorganisms and toxins) that may be present in a particular food or group of foods and are capable of causing adverse health effects.

Hazard characterization, is the qualitative or quantitative, or both, evaluation of the nature of adverse health effects associated with the biological agents which may be present in food. Preferably a dose-response assessment should be performed if the data are obtainable to assess and determine the relationship between the magnitude of exposure (dose) to a biological agent and the severity and / or frequency of adverse health effects (response).

Exposure assessment, is the qualitative or quantitative, or both, evaluation of the likely intake of biological agents through food, and it involves consideration of the frequency or likelihood of contamination of foods by the pathogenic agent and its prevalence / numbers in those food over time, up to the moment of consumption; and consumption patterns and habits.

Risk characterization is the qualitative or quantitative, or both, estimation, including attendant uncertainties, of the probability of occurrence and severity of known or potential adverse health effects in a given population based on identification, exposure assessment and hazard characterization. It provides an estimate, qualitative and/ or quantitative, of the risk. The degree of confidence in the final estimation of risk depends on the variability, uncertainty and assumptions identified in the previous steps.

Risk management is the process of weighing policy alternatives in light of the results of risk assessment and, if required, selecting and implementing appropriate control options, including regulatory measures, with a clear functional separation between risk assessment and risk management, to ensure both the scientific integrity of the risk assessment and the transparency of the decision-making management process.

Risk communication is the interactive exchange of information and opinions concerning risk among risk assessors, risk managers, consumers and other interested parties.

For the purpose of illustration, reference is made to three case studies on food borne pathogens that could have significant economic impact on public health and trade.

CASE STUDY ON *VIBRIO PARAHAEMOLYTICUS* IN TIGER PRAWN – INTERNATIONAL TRADE AND NATIONAL PUBLIC HEALTH PROTECTION

Preamble on Risk Analysis

The need for a science based approach to food safety led to the commissioning of a national risk assessment project on *V. parahaemolyticus* in Black Tiger Prawn as a priority issue in response to a request for expert advise due to the increased rejection of block frozen raw black tiger prawns from Malaysia by certain importing countries, based on their detection of the presence of *V. parahaemolyticus* in the block frozen raw black tiger prawn imported from Malaysia. *V. parahaemolyticus* is prevalent in the tropical marine environment, and is considered clinically important at the international level. In terms of trade, the fish industry is one of the major exports and income sources for Malaysia and the industry has contributed RM1.3 billion (1.5 million ton/year) or 20% to total food exports from Malaysia.

In identifying *V. parahaemolyticus* in frozen black Tiger prawns as a priority area in which it required expert risk assessment advice, the risk manager's team outlined the risk management questions as follows: Estimate the risk from exposure to *V. parahaemolyticus* due to consumption of black Tiger prawns for the Malaysian population and also the population of an importing country.

Risk Identification

The outbreak of gastroenteritis due to *V. parahaemolyticus* is a worldwide phenomenon, and in Malaysia we have reported on the prevalence of this pathogen in the environment and food sources (Son *et al.*, 1998a; 1998d; Gwendolyne *et al* 2004; Lesley *et al.*, 2005). Food poisoning reported in Malaysia in 1999 was 38.04 per 100,000 population with a gradual reduction to 36.61 in 2000, 29.99 in 2001, 28.63 in 2002 and 26.44 in the year 2003, with the episodes occurring in residential school hostels suspected to be linked to *V. parahaemolyticus* in 2002 (one), 2003 (two) and in 2004 (one), respectively. However, the issue of *V. parahaemolyticus* in seafood is getting more attention in Malaysia for economic and trade reasons, as exports of block frozen black Tiger prawns had been rejected by some EU countries due to the presence of *V. parahaemolyticus*. The rejections increased from 4 in 2000 to 4 in 2001, 10 in 2002 and 15 in 2003.

Risk Assessment

The scope of the *V. parahaemolyticus* risk assessment, and the components of the black tiger prawn industry considered were from the farm to block frozen raw black tiger prawns at point of transportation for export. The consumption of raw or undercooked contaminated seafood may lead to efficient transmission of *V. parahaemolyticus* to humans. Mild heat treatment (5 min at 50°C) of oysters, which causes at least a 4.5 log decrease in the number of viable *V. parahaemolyticus* in oysters, practically eliminates the likelihood of illness occurring. Molecular epidemiological studies revealed a strong correlation between possession of *tdh*, *trh* or both genes and the ability to cause diseases. As non-pathogenic strains can be present in seafood or environmental waters, total *V.*

parahaemolyticus counts are not enough to indicate the presence of pathogenic strains. Hence, the presence of these hemolysin genes is always considered as markers of pathogenicity in *V. parahaemolyticus*. The most probable dose-response curve for *V. parahaemolyticus* has been published by the Joint FAO/WHO Expert Consultation on Risk Assessment of Microbiological Hazards in Foods: Hazard identification, exposure assessment and hazard characterization of *Campylobacter* spp. in broiler chickens and *Vibrio* spp. in seafood (2001). Data from European border inspections show a number of seafood samples with *V. parahaemolyticus* detected, especially samples from the tropical and subtropical region where the risk of occurrence of vibrios in seafood is well known.

In this work, data obtained by the risk assessment team members, using a combination of conventional and molecular methods to determine the prevalence, concentration, and presence or absence of pathogenic and non-pathogenic strains of *V. parahaemolyticus,* were integrated in a probabilistic estimation of the risk using Monte Carlo simulation. The @RISK software package, version 4.0 (Palisade, USA), in combination with a macro produced in Visual Basic on the Excel platform, Microsoft® Excel 2000 (Microsoft, USA), were used to run the simulations (Figure 5a and 5b).

Estimate the risk from exposure to *V. parahaemolyticus* due to consumption of black Tiger prawns by the Malaysian population.

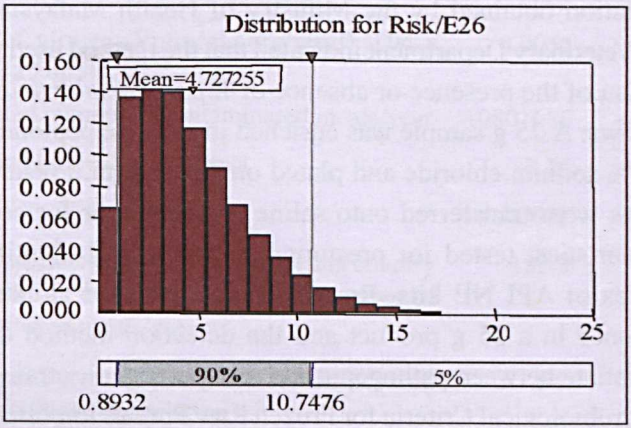

Figure 5a The mean frequency of illness by *V. parahaemolyticus* per person per year due to consumption of shrimp in Malaysia

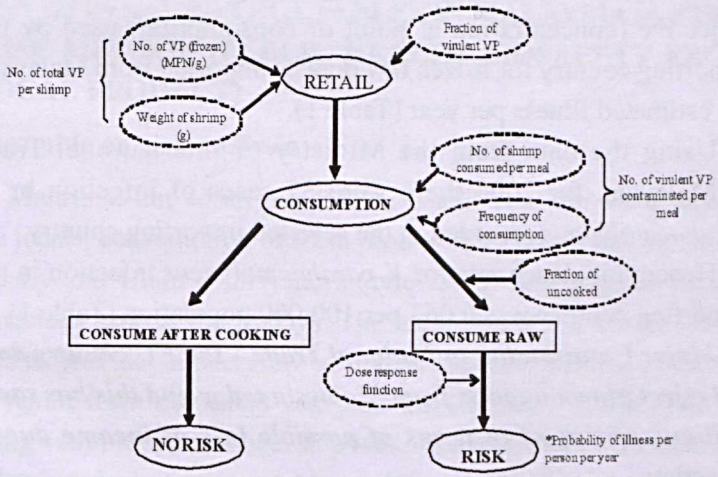

Figure 5b Model structure for risk estimation. The parameters and the outputs are shown with dotted and thick square, respectively

Estimate the risk from exposure to *V. parahaemolyticus* due to consumption of black Tiger prawns by the population in a selected importing country

Information obtained by the Ministry of Health Malaysia from Italy's Veterinary Department indicated that the method used for the detection of the presence or absence of *V. parahaemolyticus* were as follows: A 25 g sample was enriched in alkaline peptone water with 3% sodium chloride and plated on TCBS agar. Presumptive colonies were transferred onto saline nutritive agar for colonies characteristics, tested for presumed oxidation and identified in galleries of API NE kits. Results were expressed as presence or absence in a 25 g product and the detection method did not differentiate between pathogenic and non-pathogenic strains.

Microbiological Criteria for Frozen Raw Prawns imported from Malaysia set by an importing country is Absent in 25 g i.e. <1 organism/25 g of sample or <0.04 organism/g of sample.

If we assume that this microbiological criteria is the Food Safety Objective (concentration at point of consumption) used by the importing country for frozen raw prawns imported from Malaysia, the estimated illness per year (Table 1).

Using the data from the Ministry of International Trade of Malaysia, for 2004 there were 37 cases of infection by *V. parahaemolyticus* recorded in the selected importing country.

Hence: Incidence rate for *V. parahaemolyticus* infection in the importing country was 0.063 per 100,000 population (Table 1)

Major Contribution to National Trade – the EU country does not reject prawn imports from Malaysia today and this has saved millions of ringgit in terms of possible loss of income due to rejection.

Table 1 Parameters and the outputs of risk estimation

Amount consumed per meal (g)	20 g	50 g
Level of *V. parahaemolyticus* org/g	0.04	0.04
Level of virulent Vp/meal (org/meal) 0.04 x 0.7% x 20 or 50	0.0056	0.014
Estimated number of contaminated meals/year	10801680	4320673
Log level of virulent Vp/meal	-2.25	-1.85
Probability of illness	0.00001	0.00001
Estimated illness per year for importing country = Probability of illness x estimated number of contaminated meals/year	182.9	73.1
Estimated illness per year for importing country/100,000 population	0.3	0.1

CASE STUDY ON BIOSAFETY OF *CAMPYLOBACTER JEJUNI* IN SALAD VEGETABLES IN MALAYSIA: A STEP-WISE METHOD (PUBLIC HEALTH BIOSAFETY FROM LOCAL PRODUCT)

Preamble on risk analysis

In Malaysia, due to an increase in health consciousness among the locals, consumption of fresh produce like salads has increased greatly and Ulam (Malaysian's style salad) is a popular cuisine especially among the Malays. The main aim of the current work was to provide an overview of potential health hazards posed by *C. jejuni* from raw salad vegetable consumption in Malaysia by using a simple spread-sheet step-wise risk assessment. Consumers' behaviour including vegetable washing and boiling was explored in this study to demonstrate the impact of such actions in risk estimates.

Risk Identification

We have reported on the incidence of *Campylobacter* spp. from clinical, environmental and food sources (Ansary and Son, 1992; Son *et al.*, 1996; Son *et al.*, 1997; Chai *et al.*, 2007; Chai *et al.*, in press). In recent years, campylobacter have been linked to several outbreaks some of which have been traced to salad consumption (Kirk *et al.* 1997; CDC, 2000), which suggested contamination of vegetables might also be an important risk factor.

Risk Assessment

All information and data necessary to calculate the point estimates of risk (*prevalence and numbers*, *washing and boiling effect, consumption of salad vegetable, and dose response*) were gathered and incorporated into the equation models in spreadsheets (Chai *et al.*, in press). The final outcomes are point estimates of risk from *C. jejuni* for the total Malaysian population (Table 2).

According to the 2000 Population and Housing Census in Malaysia, the population in Malaysia was estimated at approximately 23.27 millions. It was estimated that roughly half of the target population consumed raw vegetables in a week and the number of infections was 11,600,095 cases if we assumed that everyone washes the vegetable before consumption. The probability of an infection resulting in symptomatic illnesses is always uncertain. Therefore, a conservative probability level 10% was chosen to estimate the risk and resulted in 1,160,010 cases of campylobacteriosis. Rapid boiling of vegetable for 10 seconds was able to reduce the incidence of campylobacteriosis to 29,088 cases per year.

Table 2 Models of equation used to calculate the risk estimates

	Equations
Dose per serving	# organisms/ serving = (# org* / g) × (g/ serving) (* concentration of C. jejuni before washing, after washing and after blanching)
Probability of infection per positive serving	$P_{inf:pos.} = 1-(1+dose/ \beta)^{-\alpha}$ ($\alpha = 0.21$ and $\beta = 59.95$)
Probability of infection per serving	$P_{inf:serv} = P_{inf:pos} \times$ Prevalence
Probability of infection per year	$P_{ann} = 1- (1-P_{inf})$ total servings annually
Expected no. of cases	$P_{ann} \times$ exposed population
Rate per 100,000	(Expected no. of cases/ total population) × 100,000

Figure 6 clearly demonstrates that the annual risk of infection was greatly reduced by lowering the prevalence of *C. jejuni* on vegetable. To lower the annual risk to 0.8, the model suggested two alternatives, one was to lower the prevalence to 10% while maintaining the dose at 3.15 log organism (1415.5 organisms); the second way was to maintain the prevalence at 40% but reducing the dose to 1.7 log organism (50 organisms). Lowering the prevalence to 10%, involves in-farm control and post-harvest practices.

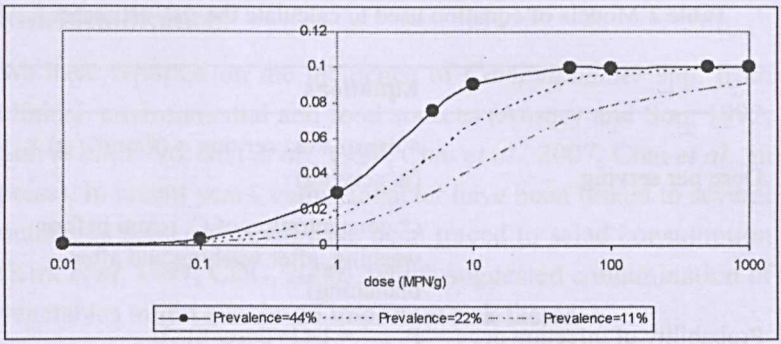

Figure 6 Demonstrates that annual risk of infection was reduced greatly by lowering the prevalence of *C. jejuni* on vegetables

CASE STUDY ON BIOSAFETY OF *LISTERIA MONOCYTOGENES* IN READY-TO-EAT CHEESE FROM ENTRY-POINTS AND RETAIL SOURCES - INFORMAL MICROBIOLOGICAL RISK ASSESSMENT (PUBLIC HEALTH BIOSAFETY FROM IMPORTED PRODUCTS)

Preamble

A proactive approach may be taken when evidence of a food-borne disease caused by a microorganism/food combination is not very clear. For example, the microorganism may be a clear food-borne hazard in one country or in association with a particular product but not yet with another and in this case the MRA can provide information on the potential risk that may occur from the hazard/food combination in a particular country or region. Or as new pathogens emerge it may be necessary to consider their potential risk as food-borne hazards. In such cases an MRA should determine the risk, and in particular gather all scientific information on the subject. This is particularly important because there may be public perception of the risk based more on articles in the popular press or

on the actions of certain pressure groups rather than on science. A good example of a proactive MRA is the study done on BSE to determine the risks of cases of variant CJD in countries where this disease had not yet presented itself.

As novel foods are being developed and new technologies are being studied, new hazards may emerge. Risks related to these developments are best anticipated in order to control unacceptable risks in time. A country has only limited possibility for the performance of MRAs. Prioritization of the pathogens and the foods is therefore important. If this is not covered by a risk profile it may be addressed in the hazard identification step. Also MRA can be used as a tool to prioritize the hazard/food combinations in terms of risk (e.g. US risk assessment on *Listeria monocytogenes* in foods was a risk-ranking exercise). This allows risk managers to have a better understanding as to which products they should focus on in order to achieve the greatest reduction in risk. This highlights some of the broad range of applications of MRA as a tool for risk managers. A good level of preparatory thinking and work will enable optimal use of this tool.

Informal Risk Assessment of *Listeria monocytogenes* in Ready-to-eat Cheese

Given its capacity to withstand a wide range of pH, osmolarity and temperature conditions, which underline many food manufacturing processes, *Listeria monocytogenes* has emerged as a significant food borne pathogen in recent decades, along with a trend toward increasing consumption of ready-to-eat and heat-and-eat convenient food products. While *L. monocytogenes* infection often produces non-specific initial manifestations (eg, influenza-like symptoms and gastroenteritis), without prompt antibiotic therapy it can have severe clinical consequences (eg, meningitis, encephalitis, septicemia and

occasional death), especially among vulnerable human population groups.

In the year 2007, I was commissioned by the Food Safety and Quality Division, Ministry of Health Malaysia to determine the prevalence and numbers of *L. monocytogenes* in ready-to-eat cheese obtained from the entry-points as well as those in the retail market. By using a combination of the most probable number (MPN), polymerase chain reaction (PCR) and plating on selective agar, I was able to report on the number and prevalence of the pathogen in the cheese samples examined. Though the numbers of positive samples were considered low, the detection of high concentrations of *L. monocytogenes* in the positive samples has raised alarm in terms of public health safety.

The findings in my study prompted the relevant authority to take a proactive approach in managing the risk by making an informal risk management decision requesting all stakeholders involved in importing cheese into Malaysia to obtain the required certification from the local authority as an assurance to provide an appropriate level of protection to consumers.

APPLICATION OF MRA IN DIFFERENT CONTEXT (UTILITY)

From the three MRAs that have been given as examples in this lecture, it can be seen that MRA is a valuable tool that can be applied to different purposes and problems in government, industries and other organizations.

Government Perspective

MRA can serve as a useful tool in the international dimension for fair commerce of safe food between nations. At the national level, it

can be used in national policy to provide advice on issues of public health, aid in transparency of decision-making and communication, and as a tool for horizon scanning or as an early warning to predict potential risk with emerging food safety issues.

Industry Perspective

The food industry generally does not use MRA but instead depends on well-recognized practices and principles such as good manufacturing practices (GMP) and the hazard analysis critical control point (HACCP) system. However, applying the principles of MRA can be of value in certain decision-making situations where variability and uncertainty exist, where the end-point of such application is a measure of an adverse outcome in terms of pathogen survival or growth, or possibly a measure of economic corporate risk.

GENETICALLY MODIFIED FOOD (GMF)

Traditionally genetic selection of seed with desirable traits from superior plants or selection of animals with desirable traits and reproduction of these through breeding has been performed and none of the current food plants resembles their wild counterpart as a result of centuries of modification to improve quality, production, and hardiness. One has only to look at the striking difference between modern corn and its grass-like ancestor, teosinte, to observe the dramatic genetic chances that have resulted from millennia of plant breeding. The products of naturally occurring interspecies crosses have been employed for thousands of years and many of the foods eaten today are derived from such crosses. A good example is cultivated hexaploid wheat, which has three different genomes, each derived from a wild ancestral species. For thousands of years,

this technology has relied upon the ability of a genetic cross to produce fertile offsprings. There are few varieties of fruits and vegetables consumed today that bear much resemblance to their wild ancestors and in spite of the striking genetic differences that have been introduced into crops, there is a long history of successful evaluation of the safety of such crops.

The use of biotechnology to modify the genetic makeup of plants to improve their agronomic and nutritional value has led to a new generation of crops, grains, and their byproducts for food and feed. Such new agricultural products have aroused an increased interest in the safety of food and feed produced from genetically modified (GM) plants. In general, with but a handful of exceptions, we have found that new foods produced through plant breeding are safe to consume. However, from a safety perspective, unintended effects of genetic modification have been speculated to manifest as the unintended expression of some unknown or unexpected toxic or antinutrient factor, or the otherwise unintended enhanced production of known toxic constituents.

The safety of our existing foods is based on long-term experience and history of safe use, even though they may contain anti-nutritional or toxic substances, as progress has been made with respect to identification and characterization of food constituents which may exert adverse and/or beneficial effects on chronic intake. In many cases beneficial compounds may also exert adverse effects, depending on the conditions and the presence of other agonists or antagonists. The scientific basis underpinning the relationship between food and its constituents and health is still fragmentary, but positive and negative effects due to the consumption of certain food constituents cannot be ignored. Thus, from the published reports, it is generally accepted that the safety assessment of genetically modified foods should be carried out on a case-by-case

basis, comparing the properties of the new food with those of a conventional counterpart. This approach, the concept of substantial equivalence, identifies potential differences between the genetically modified food and its counterpart, which should then be further assessed with respect to their safety and nutritional implications for the consumer.

My purpose here is not to make a one-sided argument on the safety of foods and food ingredients derived through biotechnology, but rather to make a plea for sound science to prevail over alarmism and emotionalism as ensuring food safety for the consumer should be the primary objective. Scientific minds should always be alert and vigilant for signs of harm or negative effects. There is no such thing as zero risk in the food supply. It would be foolish to claim that food produced through biotechnology present zero risk to consumers. The objective is to produce crops that present no new, different or unusual risks and to keep the risks within reasonably acceptable limits. Those who are opposed to the technology for reasons outside the scope of food safety would quickly respond that they will accept zero risk from a technology and an industry that they oppose.

In Malaysia, GMF products are already in the market (Tosiah *et al.*, 2006; Cheah *et al.*, 2008; Cheah and Son, 2008; Nguyen *et al.*, 2008). New foods produced through conventional breeding or introduced into the marketplace from other parts of the world are not required to undergo any type of safety assessment. They are assumed to be safe because they are comparable to other varieties (if newly introduced through conventional breeding) or because they have been safely consumed in other parts of the world. In fact, these newly introduced foods may contain numerous unique components that have not been individually or collectively assessed for safety. In contrast, products derived through biotechnology are assessed

for safety before their introduction into the food marketplace though it is a known fact that all of the existing foods produced using biotechnology has undergone a rigorous science-based safety assessment focusing on the characteristics of the products, especially the unique components.

Figures 7, 8 and 9 show the systematic approach test methods used to assess the safety of foods derived from GM crops, guidance on how to tailor the test strategy to the characteristics of the modified crop and the introduced trait and identification of potential unintended effects from the genetic modification, built on internationally agreed guidelines and principles and suitable for current and future GM crops with more complex modifications.

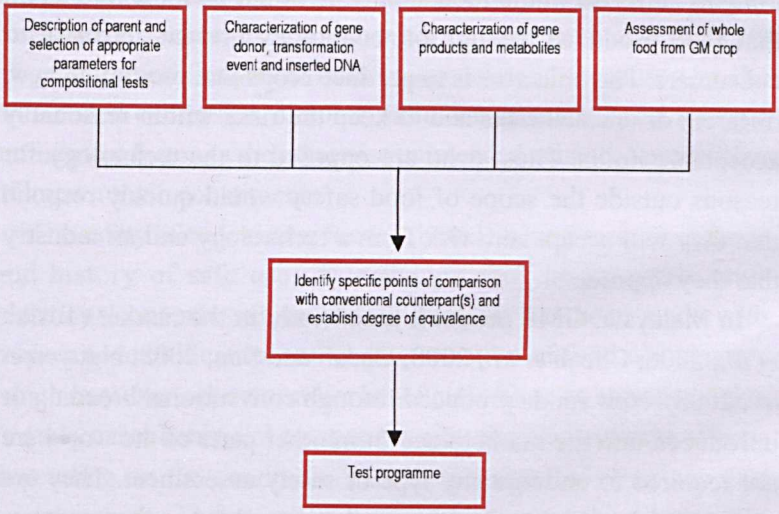

Figure 7 Typical design of a test programme for GMF

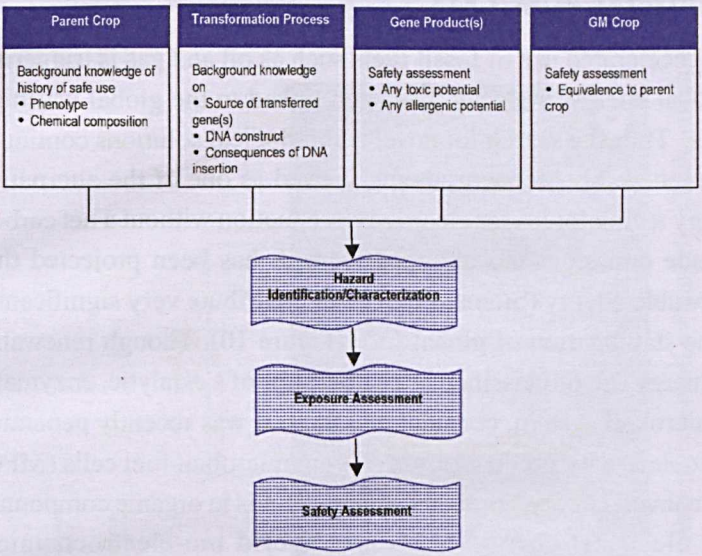

Figure 8 Elements being considered in the safety assessment of food derived from genetically modified crops

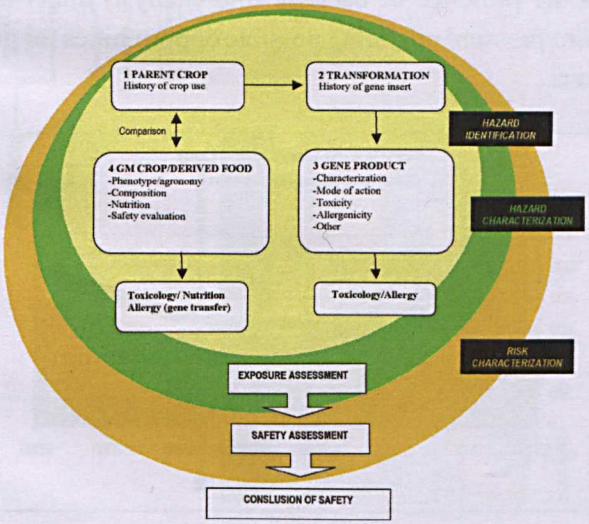

Figure 9 Safety assessment approach for genetically modified crops and derived food or feed

MICROBIAL FUEL CELL

The accelerated use of fossil fuels such as oil and gas is triggering a global energy crisis and has been linked to the global warming crisis. Thus the search for novel technological solutions continues with renewable bioenergy being viewed as one of the alternative energy technologies for electricity production without a net carbon dioxide emission into the ecosystem. It has been projected that renewable energy (biomass fuel) will contribute very significantly to the stabilization of global CO_2 (Figure 10). Though renewable bioenergy can be classified into subgroups of a catalytic, enzymatic or microbial system, considerable interest was recently generated in bioelectricity production employing microbial fuel cells (MFC) that convert energy stored in chemical bonds in organic compounds into electrical energy. MFC is a hybrid bio-electrochemical system, which converts bio-convertible substrate directly into electricity by oxidation (biodegradation) of organic matters or wastes in the presence of bacteria (bio-catalyst) under ambient temperature/pressure providing possible opportunities for practical applications.

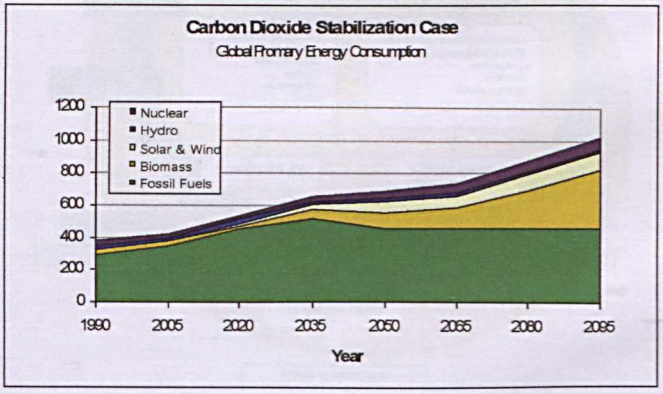

Figure 10 Potential role of biomass fuels in stabilizing global CO_2

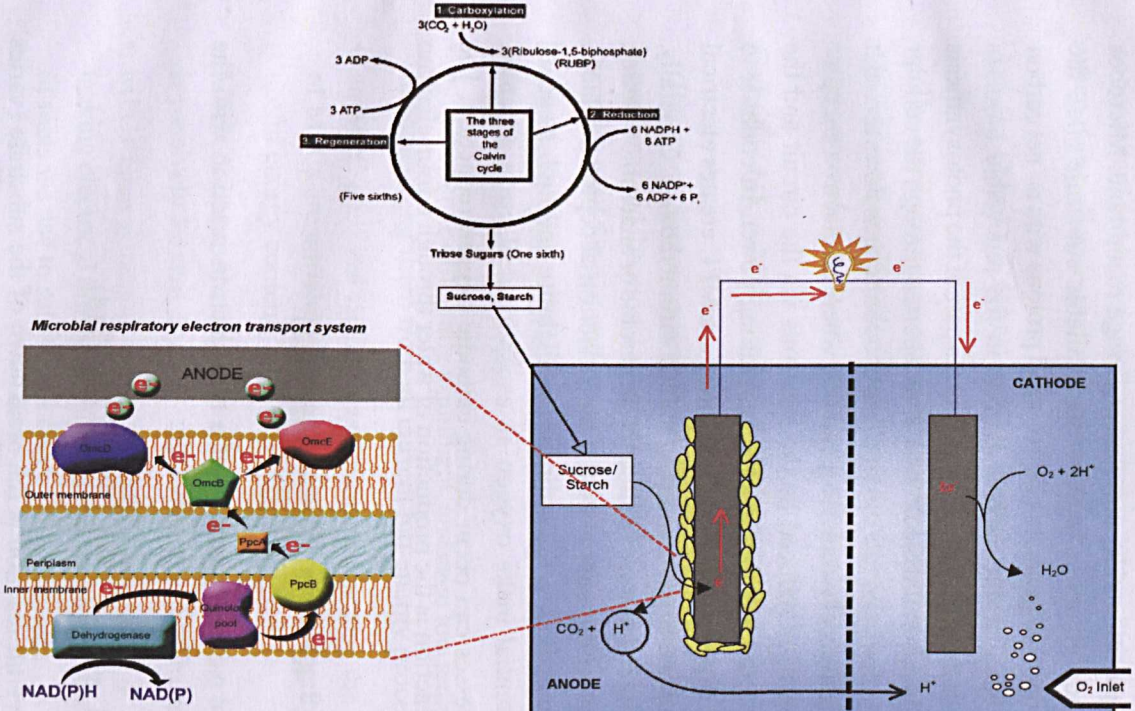

Figure 11 The working principle of a microbial fuel cell. Substrate is metabolized by bacteria, which transfers the gained electrons to the anode

Figure 11 shows a schematic diagram of a typical MFC for producing electricity, consisting basically of anodic and cathodic chambers partitioned by a proton exchange membrane. Microbes in the anode chamber oxidize the available substrate (i.e., the electron donor) to generate electrons and protons with no net carbon emission because the carbon dioxide in the renewable biomass originally comes from the atmosphere, as part of the photosynthesis process. The liberated electrons are transported through the cellular respiratory chain and released into the anode and then flows through a resistor (external circuit) to a cathode where an electron acceptor (e.g., oxygen) is reduced by the electrons via the circuit and the protons via the membrane, thus, generating power. In contrast to anaerobic digestion that produces biogas, a MFC creates electrical current and an off-gas containing mainly carbon dioxide. Generally, the cathodic reduction can either be an aerobic or anaerobic reaction depending on the source of the final electron acceptor available. In aerobic cathodes, the unlimited availability and high standard redox potential make oxygen an exceptional electron acceptor. Two processes can occur during cathodic oxygen reduction. The desired reaction is the production of water through a four-electron pathway:

$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O \ (E'^0 = 0.816V) \ (3)$$

The other pathway consists of a two-electron reaction with the production of hydrogen peroxide:

$$2O_2 + 4H^+ + 4e^- \rightarrow 2H_2O_2 \ (E'^0 = 0.295 \ V) \ (4)$$

The overall reaction is the breakdown of the substrate (varies from sugars and organic acids such as glucose or acetate to complex

polymers such as starch and cellulose, domestic, industrial, and animal waste streams) to carbon dioxide and water with a concomitant production of electricity as a by-product. For example, when using glucose as the electron donor:

Anode : $C_6H_{12}O_2 + 6H_2O \rightarrow 6CO_2 + 24H^+ + 24e^-$ (1)

The anode acts as an artificial, external electron acceptor for the microorganisms. The electrons travel through a resistor or a device to be powered, generating electricity until reaching the cathode.

Cathode : $6O_2 + 24H^+ + 24e^- \rightarrow 12H_2O$ (2)

Based on literature search on MFCs, the generally accepted operational and functional advantages of MFC over the technologies currently used for generating energy from organic matter are:

- the direct conversion of substrate energy to electricity enables high conversion efficiency
- MFCs operate efficiently at ambient, and even low temperatures, distinguishing them from all current bio-energy processes
- an MFC does not require gas treatment because the off-gases of MFCs are enriched in carbon dioxide and normally have no useful energy content
- MFCs do not need energy input for aeration provided the cathode is passively aerated, and
- MFCs have potential for widespread application in locations lacking electrical infrastructures and also to expand the diversity of fuels we use to satisfy our energy requirements.

Applications of MFC

Apart from the aforementioned application of MFCs to generate electricity from the chemical energy stored in the chemical compounds in a biomass with the aid of microorganisms, MFS can be readily modified to:

- produce hydrogen through the combination of the protons and electrons at the cathode to form hydrogen, a renewable hydrogen source that can contribute to the hydrogen demand in a hydrogen economy
- treat wastewater, e.g. sanitary wastes, food processing wastewater, swine wastewater and corn stover
- develop a biosensor method for pollutant analysis, e.g. as biological oxygen demand (BOD) sensors by measuring the proportional correlation between the Coulombic yield of MFCs and the strength of the wastewater.

Energy Payback Ratio

This is a concept that refers to the following calculation: for any given system, the energy payback is the ratio of total energy produced during the system's normal lifespan to the energy required to build, maintain and fuel the system. The higher the ratio, the higher the efficiency in terms of the ratio of energy produced to energy invested. Undoubtedly the best energy payback ratios were those from renewable energy sources such as hydropower, biomass and nuclear power (Luc Gagnon, 2008).

Microbial Fuel Cell: Novel Biotechnology For Green Energy Generation

The National energy policy in 1979 focussed on oil as the main energy resource for electricity generation. However, in 1981 the four fuel diversification policy was introduced to prevent over-dependence on oil. As a result, natural gas became the major fuel for the electricity sector (75%), followed by hydropower (10%), coal (9%) and oil (6%) (See Figure 12 as a comparative analysis between Malaysia and USA in terms of energy resources). In the year 2000, renewable energies such as biomass, biogas, municipal waste, solar, wind and fuel cells were identified and included as the fifth fuel in the energy mix of the country. Under the Small Renewable Energy Power Programme (SREP) launched in 2001, a Special Committee On Renewable Energy (SCORE) was set up to implement, promote and encourage the development of more efficient renewable energy technologies. The target was to ensure that renewable energy will contribute 5% of the country's total electricity demand by the year 2020. Table 3 shows the results of a study on renewable energy resource potential in the country (in ringgit value) (http://www.ktak.gov.my).

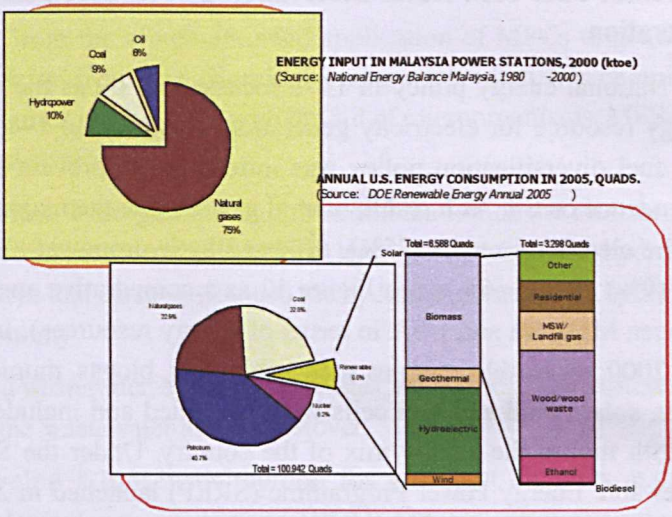

Figure 12 Energy consumption in Malaysia and USA

Table 3 Renewable energy sources in Malaysia

Renewable Energy Resource	Energy Value in RM Million (Annual)
Forest residues	11,984
Palm oil biomass	6,379
Solar thermal	3,023
Mill residues	836
Hydro	506
Solar PV	378
Municipal waste (does not include Microbial Fuel Cell)	190
Rice husk	77
Landfill gas	4

In June 2007, I obtained research funding through the Research University Grant Scheme of Universiti Putra Malaysia to initiate a study entitled "***Microbial Fuel Cell: novel biotechnology for green energy generation***" as a potential alternative to the plethora of renewable energy resources in our country using biomass as the fuel (Chai, 2008; Wong, 2008). A miniature laboratory scale two-chamber microbial fuel cell developed in my laboratory demonstrated that it is possible to generate bioelectricity production employing microbial fuel cells (MFC) that convert energy stored in chemical bonds in organic compounds to electrical energy (Figure 13).

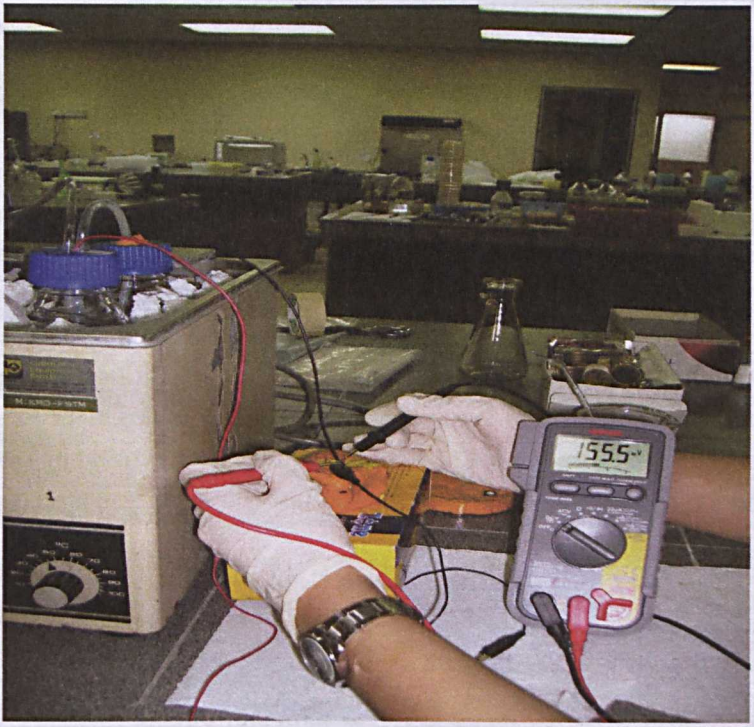

Figure 13 MFCs demonstrating power generation from microbes utilizing laboratory broth as the biofuel

Given the concerns over energy security and green house gases, national and state policies should be encouraged to promote greater utilization of biofuels (fuel cell) since Malaysia possesses sufficient natural resources to produce a substantial amount of biofuel and fuel cells from biomass, possibly enough to displace 30-50% of current petroleum-derived fuels beyond Vision 2020. According to a projection by the US DOE Genomics-to-Life (GTL) Roadmap, biomass fuels have great potential for stabilizing global carbon dioxide (Figure 10).

CONCLUSION

Instead of the long global talks about the application of "Farm to Table HACCP", we should be talking about "Farm to Table (Fork) Food Safety". The HACCP system of food safety has been oversold, raising the expectations of food safety throughout the food chain but resulting in not so transparent interactions between food safety professionals, consumers and regulators. Hence, confusion, fear and anger mount when expectations are not met. In simple terms, the food supply chain consists of seven steps: animal or crop production, slaughter or harvest, raw product production, processed product production, distribution, food service or retail operations and consumption. The most pressing food safety issues in the food industry are caused by the presence of pathogenic microbes in food products and produce and public perceptions on safety issues related to genetically modified food.

It is clear then that risk analysis deals with the evaluation of public health. It is a societal process, involving all interested parties such as consumers and industries. It may involve the commissioning of a microbiological risk assessment (MRA) and the selection and implementation of control measures based on the results. A structured approach ensures that decision-making follows a certain

procedure essential for: ensuring good order and good management practices; ensuring that all necessary information is considered; and the participation of all stakeholders. Effective consultation with relevant interested parties is essential because many control measures selected as feasible options will need to be implemented by the various businesses along the food-chain. In this lecture I have demonstrated the application of MRA in national and international trade which has greatly benefitted the country in terms of its economy and the public at large in terms of food safety.

As the technology was being developed, it was generally agreed by scientists, regulators, and policymakers that plants bred with powerful new techniques should be evaluated carefully before being put into widespread use. Safety assessment of genetically modified foods should be carried out on a case-by-case basis, comparing the properties of the new food with those of a conventional counterpart. This approach, the concept of substantial equivalence, identifies potential differences between the genetically modified food and its counterpart, which should then be further assessed with respect to its safety and nutritional implications for the consumer. I have discussed here the biosafety of GMF using science-based safety assessment focusing on the characteristics of the products. There is no such thing as zero risk in the food supply and it is unwise to claim that foods produced through biotechnology present zero risk to consumers. Usually the producers develop and release genetically modified (GM) crops that present no new, different or unusual risks and keep the risks within reasonably acceptable limits. However, todate it is obvious that those who are opposed to GM technology for reasons outside the scope of food safety argue that they will accept zero risk from a technology and an industry that they oppose.

Biomass energy potential is found to be the most promising among the renewable energy sources (RES), due to its spread and

availability worldwide. Considerable interest was recently generated in bioelectricity production employing microbial fuel cells (MFC), a bioreactor that converts chemical energy in the chemical bonds in organic compounds (biomass) to electrical energy through catalytic reactions of microorganisms. In our laboratory, we have now designed prototypes of MFCs that generate electricity. The MFCs are profiled as a sustainable core technology (i.e. basic technology adaptable to a wide variety of applications). They convert a wide array of electron donors with effective energy generation at low and moderate temperatures, even when the electron donor is provided at low concentrations. No existing technology today can match these criteria. Presumed environmental benefits are important drivers for greater use of MFCs, particularly the benefits of reduced green house gas emissions.

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BIOGRAPHY

SON RADU was born on November 14, 1962 in a small village in the Kelabit Highlands, Kubaan, Sarawak. He grew up in Bario, which is approximately a one day track on foot through the jungles and mountainous terrains from Kubaan. He completed his primary education at the Bario Primary School, attended Lutong Government Secondary School in Miri till Form Three, and finished his Form five education at the Junior Science College in Kuching. He joined the University of Malaya Foundation Studies and went on to receive his Bachelor of Science, Master of Science (Microbiology) and Doctoral (Molecular Microbiology) degrees from the University of Malaya, Malaysia.

Prior to joining Universiti Pertanian Malaysia in mid-1996, he was attached to University of Malaya as a tutor and was actively conducting research in microbiology, in addition to his research for his postgraduate degrees. His Bachelor, Master and Doctoral degrees thesis and the additional research he conducted were all published in a total of 13 peer reviewed papers in journals and 5 conference papers. This provided him with the experience to start his career in academia in UPM.

When he joined UPM, he found it to be an institution with "an attitude" with a sink-or-swim educational philosophy in which you are assumed to be knowledgeable and had to work very hard to accomplish something and publish your findings, evoking a sense of being either anointed or inadequate. He knew the rule – *publish or perish*. Immediately upon his confirmation in service with the Department of Biotechnology, UPM in February 2000 he was promoted to Associate Professor and full Professor in 2003. He was transferred to the Department of Food Science and was instrumental in expanding the Food Safety research. To date he has conducted and completed more than 30 research projects, generating more than

400 papers of which more than 150 are in refereed journals. He is still active in supervising graduate students whereby 25 Ph.D. and 47 Masters students have graduated with his guidance with another 5 Ph.D. and 10 Masters Students are currently carrying out ongoing research projects. His advice to students and new researchers is always to try to pursue what really interests and excites them as he believes that there is no substitute for enthusiasm in research.

The thing he enjoys most about a university is the interaction with students, especially the graduate students. Many people think that the ability to do multiple things simultaneously is an inability to focus or an attention deficit disorder; but to him this is the skill and trait that has led him to be involved in many things over the years and has greatly enriched his career and life. It is through his interest in research, teaching and professional services to the public and private agencies and international organization, that many rewarding door were opened for him.

With research success came local, national, and international recognition. He was involved in different committees at different times at the former Faculty of Food Science and Biotechnology and the current Faculty of Food Science and Technology in UPM. He was a regular recipient of the Faculty's excellent service award and most recently he was awarded the Universiti Putra Malaysia Excellent Service Award for year 2007. Since 2006, he has been the Editor of the International Food Research Journal (formerly ASEAN Food Journal) and is highly instrumental for promoting the journal whereby now the journal receives articles from around the world for consideration for publication and it is published on time. In addition, he is also an active reviewer for many international and national journals. Most recently, as a founding member he was appointed as the Head of the Center of Excellence for Food Safety Research in Universiti Putra Malaysia, established in August 2008.

He was awarded The Outstanding Young Malaysian 2001 Award for Academic Leadership and Achievement by the Junior Chamber of Malaysia. Todate he has been the recipient of numerous travel awards and fellowship from international organizations that enable him to travel to many conferences around the globe. He is a member of several committees such as at the Ministry of Health Malaysia on food safety, Sirim on genetically modified organisms, and Department of Standards Malaysia on laboratory accreditation, and Department of Chemistry Malaysia on genetically modified organisms. Most recently he represented the Ministry of Health Malaysia at the Joint FAO/WHO Food Standards Programme and CODEX Committee on Food Hygience Thirty-ninth Session held in New Delhi, India, which is attended by more than 100 member countries of the FAO/WHO. With the number of detention and rejection cases from the European Union member countries due to the detection of *Vibrio parahaemolyticus* in shrimp exports from Malaysia on the increase, he was commissioned by the Ministry of Health Malaysia to conduct the first Risk Assessment project on *Vibrio parahaemolyticus* in tiger prawns, the output of which was no further rejection of the commodity by the EU countries. He has and is currently also conducting several consultancy research projects on food safety (risk assessment) for the Food Safety and Quality Division of the Ministry of Health Malaysia.

From 1997 to 2005, he was actively involved in research under the Japanese Society for the Promotion of Science as an associate investigator through the University of Hokkaido which saw him traveling to Japan yearly. From the year 2000 till now, he has been inducted into the US-Japan Cooperative Medical Science Program (USJCMSP) on Emerging Infectious Diseases (Bacterial Diarrheal Diseases) in the Pacific Rim (Malaysia), receiving fellowship and funding through his research counterparts

in Kyoto University, Japan. In 1999 he was appointed the focal point of the Food and Agriculture Organization (FAO) of the United Nations in the Study of Human Pathogens and Emerging Food Safety Problems in Aquaculture, within the framework of the Asia-Pacific Fisheries Commission (APFIC) Working Group of Experts in Food Safety. This was followed by his appointment as Expert Consultant to the World Health Organization (WHO)/ Food and Agriculture Organization (FAO), Geneva, Switzerland to formulate the draft guidelines on foods derived from genetically modified microorganism/biotechnology in 2001. In the same year 2001, he was again appointed as an Expert Consultant to the Food and Agriculture Organization (FAO)/World Health Organization (WHO) of the United Nations (FAO), Rome, Italy to draft the final report on Risk Assessment of Microbiological Hazards in Foods, specifically on Risk Characterization of *Salmonella* spp. in eggs and broiler chicken and *Listeria monocytogenes* in ready-to-eat foods. He was once again appointed and involved in the World Health Organization (WHO) Global Salmonella-Survey (GSS) (www.who.int/salmsurv) and World Health Organization (WHO) Global Salm-Surv's (GSS) External Quality Assurance System (EQAS) Panel (globalsalm-surv@listserv.dcd.gov / www.who.ch/salmsurv). He was also appointed as the Expert Consultant to the European Commission (EC)-ASEAN Economic Cooperation Programme on Standards, Quality and Conformity Assessment on genetically modified organisms (GMO) in 2005. Currently he is the FAO/WHO Network on Microbiological Risk Assessment resource person, trainer and web master for the FAO/WHO Microbiological Risk Assessment in the South East Asian Regional Network, an initiative in Collaboration with the Center of Excellence for Food Safety Research Centre, UPM (as the hosting institution), a basic web-based regional risk assessment portal created to provide details

to contacts, news and events and technical materials. The purpose of the network is to strengthen capacity building on MRA among risk managers, risk assessors and others in countries in Asia. Since 2005, he has been on the board of the Science Advisory Committee of the International Foundation for Science, Sweden (meeting twice a year) and recently he has been given the task of promoting and conducting workshops in developing countries on food safety in the Asian and African region.

In retrospect, I feel that God has blessed me to prosper by being in the right place at the right time; picking the most interesting and significant field of science (food safety and microbiology) to study that has led to an interesting and productive career; having lived and worked with outstanding colleagues and friends; to have a wonderful wife (Dora) and two great children (Daniel and Kimberley) who are part of a close and loving family. Words of wisdom that I can timidly offer is that "Chance favors the prepared mind."

ACKNOWLEDGEMENTS

I am ever grateful to God for giving me the strength and wisdom that allows me to fulfill my purpose and potential. Looking back, I can see clearly the path with all its twists and turns that has led me to this current point in my career that is sometimes full of serendipity and surprises. In my life stories, places and people play important roles and for that I feel a deep sense of gratitude to:

* my wonderful wife, Dora and our children, Daniel and Kimberley for their patience, understanding and support during my many travels and involvements outside the home. You make it easy to fulfill God's will.
* my mother (Lipang Aren) and late father (Apui Mayu Balang) whose vision has brought me from the deep interior jungle of Borneo into the Global Village, and my brothers and sisters.
* all staff of the Faculty of Food Science and Technology, UPM for their passion for excellence and for providing an environment that is productive, stimulating and fun.
* all my undergraduate and graduate (Master and Doctoral) students who are directly engaged in my research projects and where in almost all my publications at least one of my student is coauthor/presenter.
* my close circle of friends and research collaborators in Malaysia and outside Malaysia.

LIST OF INAUGURAL LECTURES

1. Prof. Dr. Sulaiman M. Yassin
   The Challenge to Communication Research in Extension
   22 July 1989

2. Prof. Ir. Abang Abdullah Abang Ali
   Indigenous Materials and Technology for Low Cost Housing
   30 August 1990

3. Prof. Dr. Abdul Rahman Abdul Razak
   Plant Parasitic Nematodes, Lesser Known Pests of Agricultural Crops
   30 January 1993

4. Prof. Dr. Mohamed Suleiman
   Numerical Solution of Ordinary Differential Equations: A Historical Perspective
   11 December 1993

5. Prof. Dr. Mohd. Ariff Hussein
   Changing Roles of Agricultural Economics
   5 March 1994

6. Prof. Dr. Mohd. Ismail Ahmad
   Marketing Management: Prospects and Challenges for Agriculture
   6 April 1994

7. Prof. Dr. Mohamed Mahyuddin Mohd. Dahan
   The Changing Demand for Livestock Products
   20 April 1994

8. Prof. Dr. Ruth Kiew
   Plant Taxonomy, Biodiversity and Conservation
   11 May 1994

9. Prof. Ir. Dr. Mohd. Zohadie Bardaie
   Engineering Technological Developments Propelling Agriculture into the 21st Century
   28 May 1994

10. Prof. Dr. Shamsuddin Jusop
    Rock, Mineral and Soil
    18 June 1994

11. Prof. Dr. Abdul Salam Abdullah
Natural Toxicants Affecting Animal Health and Production
29 June 1994

12. Prof. Dr. Mohd. Yusof Hussein
Pest Control: A Challenge in Applied Ecology
9 July 1994

13. Prof. Dr. Kapt. Mohd. Ibrahim Haji Mohamed
Managing Challenges in Fisheries Development through Science and Technology
23 July 1994

14. Prof. Dr. Hj. Amat Juhari Moain
Sejarah Keagungan Bahasa Melayu
6 Ogos 1994

15. Prof. Dr. Law Ah Theem
Oil Pollution in the Malaysian Seas
24 September 1994

16. Prof. Dr. Md. Nordin Hj. Lajis
Fine Chemicals from Biological Resources: The Wealth from Nature
21 January 1995

17. Prof. Dr. Sheikh Omar Abdul Rahman
Health, Disease and Death in Creatures Great and Small
25 February 1995

18. Prof. Dr. Mohamed Shariff Mohamed Din
Fish Health: An Odyssey through the Asia - Pacific Region
25 March 1995

19. Prof. Dr. Tengku Azmi Tengku Ibrahim
Chromosome Distribution and Production Performance of Water Buffaloes
6 May 1995

20. Prof. Dr. Abdul Hamid Mahmood
Bahasa Melayu sebagai Bahasa Ilmu- Cabaran dan Harapan
10 Jun 1995

21. Prof. Dr. Rahim Md. Sail
Extension Education for Industrialising Malaysia: Trends, Priorities and Emerging Issues
22 July 1995

22. Prof. Dr. Nik Muhammad Nik Abd. Majid
The Diminishing Tropical Rain Forest: Causes, Symptoms and Cure
19 August 1995

23. Prof. Dr. Ang Kok Jee
The Evolution of an Environmentally Friendly Hatchery Technology for Udang Galah, the King of Freshwater Prawns and a Glimpse into the Future of Aquaculture in the 21st Century
14 October 1995

24. Prof. Dr. Sharifuddin Haji Abdul Hamid
Management of Highly Weathered Acid Soils for Sustainable Crop Production
28 October 1995

25. Prof. Dr. Yu Swee Yean
Fish Processing and Preservation: Recent Advances and Future Directions
9 December 1995

26. Prof. Dr. Rosli Mohamad
Pesticide Usage: Concern and Options
10 February 1996

27. Prof. Dr. Mohamed Ismail Abdul Karim
Microbial Fermentation and Utilization of Agricultural Bioresources and Wastes in Malaysia
2 March 1996

28. Prof. Dr. Wan Sulaiman Wan Harun
Soil Physics: From Glass Beads to Precision Agriculture
16 March 1996

29. Prof. Dr. Abdul Aziz Abdul Rahman
Sustained Growth and Sustainable Development: Is there a Trade-Off 1 or Malaysia
13 April 1996

30. Prof. Dr. Chew Tek Ann
Sharecropping in Perfectly Competitive Markets: A Contradiction in Terms
27 April 1996

31. Prof. Dr. Mohd. Yusuf Sulaiman
Back to the Future with the Sun
18 May 1996

32. Prof. Dr. Abu Bakar Salleh
Enzyme Technology: The Basis for Biotechnological Development
8 June 1996

33. Prof. Dr. Kamel Ariffin Mohd. Atan
The Fascinating Numbers
29 June 1996

34. Prof. Dr. Ho Yin Wan
Fungi: Friends or Foes
27 July 1996

35. Prof. Dr. Tan Soon Guan
Genetic Diversity of Some Southeast Asian Animals: Of Buffaloes and Goats and Fishes Too
10 August 1996

36. Prof. Dr. Nazaruddin Mohd. Jali
Will Rural Sociology Remain Relevant in the 21st Century?
21 September 1996

37. Prof. Dr. Abdul Rani Bahaman
Leptospirosis-A Model for Epidemiology, Diagnosis and Control of Infectious Diseases
16 November 1996

38. Prof. Dr. Marziah Mahmood
Plant Biotechnology - Strategies for Commercialization
21 December 1996

39. Prof. Dr. Ishak Hj. Omar
Market Relationships in the Malaysian Fish Trade: Theory and Application
22 March 1997

40. Prof. Dr. Suhaila Mohamad
Food and Its Healing Power
12 April 1997

41. Prof. Dr. Malay Raj Mukerjee
A Distributed Collaborative Environment for Distance Learning Applications
17 June 1998

42. Prof. Dr. Wong Kai Choo
Advancing the Fruit Industry in Malaysia: A Need to Shift Research Emphasis
15 May 1999

43. Prof. Dr. Aini Ideris
Avian Respiratory and Immunosuppressive Diseases- A Fatal Attraction
10 July 1999

44. Prof. Dr. Sariah Meon
Biological Control of Plant Pathogens: Harnessing the Richness of Microbial Diversity
14 August 1999

45. Prof. Dr. Azizah Hashim
The Endomycorrhiza: A Futile Investment?
23 Oktober 1999

46. Prof. Dr. Noraini Abdul Samad
Molecular Plant Virology: The Way Forward
2 February 2000

47. Prof. Dr. Muhamad Awang
Do We Have Enough Clean Air to Breathe?
7 April 2000

48. Prof. Dr. Lee Chnoong Kheng
Green Environment, Clean Power
24 June 2000

49. Prof. Dr. Mohd. Ghazali Mohayidin
Managing Change in the Agriculture Sector: The Need for Innovative Educational Initiatives
12 January 2002

50. Prof. Dr. Fatimah Mohd. Arshad
Analisis Pemasaran Pertanian di Malaysia: Keperluan Agenda Pembaharuan
26 Januari 2002

51. Prof. Dr. Nik Mustapha R. Abdullah
Fisheries Co-Management: An Institutional Innovation Towards Sustainable Fisheries Industry
28 February 2002

52. Prof. Dr. Gulam Rusul Rahmat Ali
Food Safety: Perspectives and Challenges
23 March 2002

53. Prof. Dr. Zaharah A. Rahman
Nutrient Management Strategies for Sustainable Crop Production in Acid Soils: The Role of Research Using Isotopes
13 April 2002

54. Prof. Dr. Maisom Abdullah
Productivity Driven Growth: Problems & Possibilities
27 April 2002

55. Prof. Dr. Wan Omar Abdullah
Immunodiagnosis and Vaccination for Brugian Filariasis: Direct Rewards from Research Investments
6 June 2002

56. Prof. Dr. Syed Tajuddin Syed Hassan
Agro-ento Bioinformation: Towards the Edge of Reality
22 June 2002

57. Prof. Dr. Dahlan Ismail
Sustainability of Tropical Animal-Agricultural Production Systems: Integration of Dynamic Complex Systems
27 June 2002

58. Prof. Dr. Ahmad Zubaidi Baharumshah
The Economics of Exchange Rates in the East Asian Countries
26 October 2002

59. Prof. Dr. Shaik Md. Noor Alam S.M. Hussain
Contractual Justice in Asean: A Comparative View of Coercion
31 October 2002

60. Prof. Dr. Wan Md. Zin Wan Yunus
Chemical Modification of Polymers: Current and Future Routes for Synthesizing New Polymeric Compounds
9 November 2002

61. Prof. Dr. Annuar Md. Nassir
Is the KLSE Efficient? Efficient Market Hypothesis vs Behavioural Finance
23 November 2002

62. Prof. Ir. Dr. Radin Umar Radin Sohadi
Road Safety Interventions in Malaysia: How Effective Are They?
21 February 2003

63. Prof. Dr. Shamsher Mohamad
The New Shares Market: Regulatory Intervention, Forecast Errors and Challenges
26 April 2003

64. Prof. Dr. Han Chun Kwong
Blueprint for Transformation or Business as Usual? A Structurational Perspective of the Knowledge-Based Economy in Malaysia
31 May 2003

65. Prof. Dr. Mawardi Rahmani
Chemical Diversity of Malaysian Flora: Potential Source of Rich Therapeutic Chemicals
26 July 2003

66. Prof. Dr. Fatimah Md. Yusoff
An Ecological Approach: A Viable Option for Aquaculture Industry in Malaysia
9 August 2003

67. Prof. Dr. Mohamed Ali Rajion
The Essential Fatty Acids-Revisited
23 August 2003

68. Prof. Dr. Azhar Md. Zain
Psychotheraphy for Rural Malays - Does it Work?
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69. Prof. Dr. Mohd. Zamri Saad
Respiratory Tract Infection: Establishment and Control
27 September 2003

70. Prof. Dr. Jinap Selamat
Cocoa-Wonders for Chocolate Lovers
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71. Prof. Dr. Abdul Halim Shaari
High Temperature Superconductivity: Puzzle & Promises
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72. Prof. Dr. Yaakob Che Man
Oils and Fats Analysis - Recent Advances and Future Prospects
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73. Prof. Dr. Kaida Khalid
Microwave Aquametry: A Growing Technology
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74. Prof. Dr. Hasanah Mohd. Ghazali
Tapping the Power of Enzymes- Greening the Food Industry
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75. Prof. Dr. Yusof Ibrahim
The Spider Mite Saga: Quest for Biorational Management Strategies
22 May 2004

76. Prof. Datin Dr. Sharifah Md. Nor
The Education of At-Risk Children: The Challenges Ahead
26 June 2004

77. Prof. Dr. Ir. Wan Ishak Wan Ismail
Agricultural Robot: A New Technology Development for Agro-Based Industry
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78. Prof. Dr. Ahmad Said Sajap
Insect Diseases: Resources for Biopesticide Development
28 August 2004

79. Prof. Dr. Aminah Ahmad
The Interface of Work and Family Roles: A Quest for Balanced Lives
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80. Prof. Dr. Abdul Razak Alimon
Challenges in Feeding Livestock: From Wastes to Feed
23 April 2005

81. Prof. Dr. Haji Azimi Hj. Hamzah
Helping Malaysian Youth Move Forward: Unleashing the Prime Enablers
29 April 2005

82. Prof. Dr. Rasedee Abdullah
In Search of An Early Indicator of Kidney Disease
27 May 2005

83. Prof. Dr. Zulkifli Hj. Shamsuddin
Smart Partnership: Plant-Rhizobacteria Associations
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84. Prof. Dr. Mohd Khanif Yusop
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8 July 2005

86. Prof. Dr. Othman Mohamed
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87. Prof. Ir. Dr. Mohd Amin Mohd Soom
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88. Prof. Dr. Mohd Arif Syed
Bioremediation-A Hope Yet for the Environment?
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89. Prof. Dr. Abdul Hamid Abdul Rashid
The Wonder of Our Neuromotor System and the Technological Challenges They Pose
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90. Prof. Dr. Norhani Abdullah
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91. Prof. Dr. Abdul Aziz Saharee
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92. Prof. Dr. Kamariah Abu Bakar
Activating Teachers' Knowledge and Lifelong Journey in Their Professional Development
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24 March 2006

94. Prof. Dr. Sundararajan Thilagar
Development and Innovation in the Fracture Management of Animals
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95. Prof. Dr. Zainal Aznam Md. Jelan
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96. Prof. Dr. Mahiran Basri
Green Organic Chemistry: Enzyme at Work
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20 April 2007

98. Prof. Dr. Khalid Abdul Rahim
Trade and Sustainable Development: Lessons from Malaysia's Experience
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99. Prof. Dr. Mad Nasir Shamsudin
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100. Prof. Dr. Zainal Abidin Mohamed
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101. Prof. Ir. Dr. Mohamed Daud
Expert Systems for Environmental Impacts and Ecotourism Assessments
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102. Prof. Dr. Saleha Abdul Aziz
Pathogens and Residues; How Safe is Our Meat?
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103. Prof. Dr. Jayum A. Jawan
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7 Disember 2007

104. Prof. Dr. Zakariah Abdul Rashid
Planning for Equal Income Distribution in Malaysia: A General Equilibrium Approach
28 December 2007

105. Prof. Datin Paduka Dr. Khatijah Yusoff
Newcastle Disease virus: A Journey from Poultry to Cancer
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106. Prof. Dr. Dzulkefly Kuang Abdullah
Palm Oil: Still the Best Choice
1 February 2008

107. Prof. Dr. Elias Saion
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22 February 2008

108. Prof. Dr. Mohd Ali Hassan
Waste-to-Wealth Through Biotechnology: For Profit, People and Planet
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109. Prof. Dr. Mohd Maarof H. A. Moksin
Metrology at Nanoscale: Thermal Wave Probe Made It Simple
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110. Prof. Dr. Dzolkhifli Omar
The Future of Pesticides Technology in Agriculture: Maximum Target Kill with Minimum Collateral Damage
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111. Prof. Dr. Mohd. Yazid Abd. Manap
Probiotics: Your Friendly Gut Bacteria
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112. Prof. Dr. Hamami Sahri
Sustainable Supply of Wood and Fibre: Does Malaysia have Enough?
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113. Prof. Dato' Dr. Makhdzir Mardan
Connecting the Bee Dots
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114. Prof. Dr. Maimunah Ismail
Gender & Career: Realities and Challenges
25 July 2008

115. Prof. Dr. Nor Aripin Shamaan
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1 August 2008

116. Prof. Dr. Mohd Yunus Abdullah
Penjagaan Kesihatan Primer di Malaysia: Cabaran Prospek dan Implikasi dalam Latihan dan Penyelidikan Perubatan serta Sains Kesihatan di Universiti Putra Malaysia
8 Ogos 2008

117. Prof. Dr. Musa Abu Hassan
Memanfaatkan Teknologi Maklumat & Komunikasi ICT untuk Semua
15 Ogos 2008

118. Prof. Dr. Md. Salleh Hj. Hassan
Role of Media in Development: Strategies, Issues & Challenges
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