Foodborne Pathogens


Significance: A predictive model was developed to evaluate the effects of water activity, temperature and food composition on thermal inactivation of Salmonella in foods.

Salmonella can survive in low-moisture, high-protein, and high-fat foods for several years. Despite nationwide outbreaks and recalls due to the presence of Salmonella in low-moisture foods, information on thermal inactivation of Salmonella in these products is limited. This project evaluated the impact of water activity (a_w), temperature, and food composition on thermal inactivation of Salmonella enterica serovar Agona in defined high-protein and high-fat model food matrices. Each matrix was inoculated with Salmonella Agona and adjusted to obtain a target a_w, ranging from 0.50 to 0.98. Samples were packed into aluminum test cells and heated (52 to 90°C) under isothermal conditions. Survival of Salmonella Agona was detected on tryptic soy agar with 0.6% yeast extract. Complex influences by food composition, a_w, and temperature resulted in significantly different (P < 0.05) thermal resistance of Salmonella for the conditions tested. It was estimated that the same point temperatures at which the D-values of the two matrices at each a_w (0.63, 0.73, 0.81, and 0.90) were identical were 79.48, 71.28, 69.62, and 38.42°C, respectively. Above these temperatures, the D-values in high-protein matrices were larger than the D-values in high-fat matrices at each a_w. Below these temperatures, the inverse relationship was observed. A correlation between temperature and a_w existed on the basis of the level of fat or protein in the food, showing that these compositional factors must be accounted for when predicting thermal inactivation of Salmonella in foods.

Modelling the Microbial Dynamics and Antimicrobial Resistance Development of Listeria in Viscoelastic Food Model Systems of Various Structural Complexities


Significance: This study characterizes the impact of food structural complexity and the natural antimicrobial nisin on growth dynamics of Listeria innocua.

Minimal processing for microbial decontamination, such as the use of natural antimicrobials, is gaining interest in the food industry as these methods are generally milder than conventional processing, therefore better maintaining the nutritional content and sensory characteristics of food products. The aim of this study was to quantify the impact of (i) structural composition and complexity, (ii) growth location and morphology, and (iii) the natural antimicrobial nisin, on the microbial dynamics of Listeria innocua. More specifically, viscoelastic food model systems of various compositions and internal structure were developed and characterised, i.e. monophasic Xanthan gum-based and biphasic Xanthan gum/Whey protein-based viscoelastic systems. The microbial dynamics of L. innocua at 10 °C, 30 °C and 37 °C were monitored and compared for planktonic growth in liquid, or in/on (immersed or surface colony growth) the developed viscoelastic systems, with or without a sublethal concentration of nisin. Microscopy imaging was used to determine the bacterial colony size and spatial organisation in/on the viscoelastic systems. Selective growth of L. innocua on the protein phase of the developed biphasic system was observed for the first time. Additionally, significant differences were observed in the colony size and distribution in the monophasic Xanthan gum-based systems depending on (i) the type of growth (surface/immersed) and (ii) the Xanthan gum concentration. Furthermore, the system viscosity in monophasic Xanthan gum-based systems had a protective role against the effects of nisin for immersed growth, and a further inhibitory effect for surface growth at a suboptimal temperature (10 °C). These findings give a systematic quantitative insight on the impact of nisin as an environmental challenge on the growth and spatial organisation of L. innocua, in viscoelastic food model systems of various structural compositions/complexities. This study highlights the importance of accounting for system structural composition/complexity when designing minimal food processing methods with natural antimicrobials.
**Pathogen Detection**

**Growth, Detection and Virulence of Listeria monocytogenes in the Presence of Other Microorganisms: Microbial Interactions from Species to Strain Level**


**Significance:** The impact of microbial interactions on the growth and detection of *L. monocytogenes* in foods and food-associated environments is summarized.

Like with all food microorganisms, many basic aspects of *L. monocytogenes* life are likely to be influenced by its interactions with bacteria living in close proximity. This pathogenic bacterium is a major concern both for the food industry and health organizations since it is ubiquitous and able to withstand harsh environmental conditions. Due to the ubiquity of *Listeria monocytogenes*, various strains may contaminate foods at different stages of the supply chain. Consequently, simultaneous exposure of consumers to multiple strains is also possible. In this context even strain-to-strain interactions of *L. monocytogenes* play a significant role in fundamental processes for the life of the pathogen, such as growth or virulence, and subsequently compromise food safety, affect the evolution of a potential infection, or even introduce bias in the detection by classical enrichment techniques. This article summarizes the impact of microbial interactions on the growth and detection of *L. monocytogenes* primarily in foods and food-associated environments. Furthermore it provides an overview of *L. monocytogenes* virulence in the presence of other microorganisms.

**Food Processing Safety**

**Inactivation of Microorganisms in Foods by Ohmic Heating: A Review**


**Significance:** Advantages of Ohmic heating and factors that influence its effectiveness for microbial inactivation are presented.

Ohmic heating (OH) is an alternative food processing technology for effectively inactivating microorganisms that depends on the heat that has been generated when electrical current passes directly through food material. The advantages of OH for microbial inactivation include shorter heating time, more uniform heat distribution inside food, reduced nutrition losses, and higher energy efficiency. This review presents some published information regarding the inactivation of microorganisms by OH, including the major factors that influence the inactivation effectiveness of OH, the inactivation of vegetative cells and spores in foods by OH, the inactivation mechanisms of OH, and the challenges and prospects of OH for food processing. This information will improve the understanding of OH for inactivation of microorganisms and promote the application of OH in the food industry.

**Novel Approaches for Chemical and Microbiological Shelf Life Extension of Cereal Crops**


**Significance:** Novel alternatives to chemical cereal crop decontaminants are presented, including potential advantages and barriers for industrial application.

Economic losses due to post-harvest fungal spoilage and mycotoxin contamination of cereal crops is a frequently encountered issue. Typically, chemical preservatives are used to reduce the initial microbial load and the environmental conditions during storage are controlled to prevent microbial growth. However, in recent years the consumers’ desire for more naturally produced foods containing less chemical preservatives has grown increasingly stronger. This article reviews the latest advances in terms of novel approaches for chemical decontamination, namely application cold atmospheric pressure plasma and electrolysed water, and their suitability for preservation of stored cereal crops. In addition, the alternative use of bio-preservatives, such as starter cultures or purified antimicrobial compounds, to prevent the growth of spoilage organisms or remove in-field accumulated mycotoxins is evaluated. All treatments assessed here show potential for inhibition of microbial spoilage. However, each method encounters draw-backs, making industrial application difficult. Even under optimised processing conditions, it is unlikely that one single treatment can reduce
the natural microbial load sufficiently. It is evident that future research needs to examine the combined application of several treatments to exploit their synergistic properties. This would enable sufficient reduction in the microbial load and ensure microbiological safety of cereal crops during long-term storage.

**Risk Assessment**

**Comprehensive Analyses and Prioritization of Tox21 10K Chemicals Affecting Mitochondrial Function by in-Depth Mechanistic Studies**


**Significance:** A tier-based approach was used to identify and characterize chemicals that affect mitochondrial function.

**Background:** A central challenge in toxicity testing is the large number of chemicals in commerce that lack toxicological assessment. In response, the Tox21 program is re-focusing toxicity testing from animal studies to less expensive and higher throughput in vitro methods using target/pathway-specific, mechanism-driven assays. Objectives: Our objective was to use an in-depth mechanistic study approach to prioritize and characterize the chemicals affecting mitochondrial function. Methods: We used a tiered testing approach to prioritize for more extensive testing 622 compounds identified from a primary, quantitative high-throughput screen of 8,300 unique small molecules, including drugs and industrial chemicals, as potential mitochondrial toxicants by their ability to significantly decrease the mitochondrial membrane potential (MMP). Based on results from secondary MMP assays in HepG2 cells and rat hepatocytes, 34 compounds were selected for testing in tertiary assays that included formation of reactive oxygen species (ROS), upregulation of p53 and nuclear erythroid 2-related factor 2/antioxidant response element (Nrf2/ARE), mitochondrial oxygen consumption, cellular Parkin translocation, and larval development and ATP status in the nematode Caenorhabditis elegans. Results: A group of known mitochondrial complex inhibitors (e.g., rotenone) and uncouplers (e.g., chlorfenapyr), as well as potential novel complex inhibitors and uncouplers, were detected. From this study, we identified four not well-characterized potential mitochondrial toxicants (lasalocid, picoxystrobin, pinacyanol, and triclocarban) that merit additional in vivo characterization. Conclusions: The tier-based approach for identifying and mechanistically characterizing mitochondrial toxicants can potentially reduce animal use in toxicological testing.

**Recent Advancements in Lateral Flow Immunoassays: A Journey for Toxin Detection in Food**


**Significance:** This paper highlights factors that influence sensitivities and specificities of lateral flow immunoassays for detecting toxins in food, and suggests ways to improve this technology in the future.

Biotechnology embraces various physical and chemical phenomena toward advancement of health diagnostics. Toward such advancement, detection of toxins plays an important role. Toxins produce severe health impacts on consumption with high mortality associated in acute cases. The most prominent route of infection and intoxication is through food matrices. Therefore, rapid detection of toxins at low concentrations is the need of modern diagnostics. Lateral flow immunoassays are one of the emergent and popularly used rapid detection technology developed for detecting various kinds of analytes. This review thus focuses on recent advancements in lateral flow immunoassays for detecting different toxins in agricultural food. Appropriate emphasis was given on how the labels, recognition elements, or detection strategy has laid an impact on improvement in immunochromatographic assays for toxins. The paper also discusses the gradual change in sensitivities and specificities of assays in accordance with the method of food processing used. The review concludes with the major challenges faced by this technology and provides an outlook and insight of ideas to improve it in the future.

**Nanomaterials**

**Improving the Antimicrobial Power of Low-Effective Antimicrobial Molecules Through Nanotechnology**


**Significance:** A novel, powerful antimicrobial agent based on a nanomaterial anchored to a non-antimicrobial organic molecule was developed.

The objective of this work was on the one hand to assess the antibacterial activity of amines anchored to the external surface of mesoporous silica particles against Listeria monocytogenes in comparison with the same dose of free amines as well. It was also our aim to elucidate the mechanism of action of the new antimicrobial device. The suitability of silica nanoparticles to anchor,
concentrate and improve the antimicrobial power of polyamines against L. monocytogenes has been demonstrated in a saline solution and in a food matrix. Moreover, through microscope observations it has been possible to determine that the attractive binding forces between the positive amine corona on the surface of nanoparticles and the negatively charged bacteria membrane provoke a disruption of the cell membrane. The surface concentration of amines on the surface of the nanoparticles is so effective that immobilized-amines were 100 times more effective in killing L. monocytogenes bacteria than the same amount of free polyamines. This novel approach for the creation of antimicrobial nanodevices opens the possibility to put in value the antimicrobial power of natural molecules that have been discarded because of its low antimicrobial power. Practical Application: Consumers demand for high-quality products, free from chemical preservatives, with an extended shelf-life. In this study, a really powerful antimicrobial agent based on a nanomaterial functionalized with a non-antimicrobial organic molecule was developed as a proof of concept. Following this approach it could be possible to develop a new generation of natural and removable antimicrobials based on their anchoring to functional surfaces for food, agricultural or medical purposes.

Heavy Metals

Evaluation of a Physiologically Based Pharmacokinetic (PBPK) Model for Inorganic Arsenic Exposure Using Data from Two Diverse Human Populations


Significance: The adequacy of a previously published physiologically based pharmacokinetic model for inorganic arsenic exposure was assessed.

Background: Multiple epidemiological studies exist for some of the well-studied health endpoints associated with inorganic arsenic (iAs) exposure; however, results are usually expressed in terms of different exposure/dose metrics. Physiologically based pharmacokinetic (PBPK) models may be used to obtain a common exposure metric for application in dose-response meta-analysis. Objective: A previously published PBPK model for inorganic arsenic (iAs) was evaluated using data sets for arsenic-exposed populations from Bangladesh and the United States. Methods: The first data set was provided by the Health Effects of Arsenic Longitudinal Study cohort in Bangladesh. The second data set was provided by a study conducted in Churchill County, Nevada, USA. The PBPK model consisted of submodels describing the absorption, distribution, metabolism and excretion (ADME) of iAs and its metabolites monomethylarsenic (MMA) and dimethylarsenic (DMA) acids. The model was used to estimate total arsenic levels in urine in response to oral ingestion of iAs. To compare predictions of the PBPK model against observations, urinary arsenic concentration and creatinine-adjusted urinary arsenic concentration were simulated. As part of the evaluation, both water and dietary intakes of arsenic were estimated and used to generate the associated urine concentrations of the chemical in exposed populations. Results: When arsenic intake from water alone was considered, the results of the PBPK model under-predicted urinary arsenic concentrations for individuals with low levels of arsenic in drinking water and slightly overpredicted urinary arsenic concentrations in individuals with higher levels of arsenic in drinking water. When population-specific estimates of dietary intakes of iAs were included in exposures, the predictive value of the PBPK model was markedly improved, particularly at lower levels of arsenic intake. Conclusions: Evaluations of this PBPK model illustrate its adequacy and usefulness for oral exposure reconstructions in human health risk assessment, particularly in individuals who are exposed to relatively low levels of arsenic in water or food.

Food Packaging

Scientific Advances and Challenges in Safety Evaluation of Food Packaging Materials: Workshop Proceedings


Significance: These proceedings discuss the state of the science regarding the safety of food packaging, and highlights challenges and research gaps that this rapidly evolving field faces.

Packaging is an indispensable component of the food manufacturing and food supply process. This scientific workshop was convened to bring together scientists from government, academia, and industry to discuss the state of the science regarding the safety of food packaging, prompted by rapidly advancing research to improve food packaging that continues to impact packaging technology, toxicology, exposure, risk assessment, and sustainability. The opening session focused on scientific challenges in the safety assessment of food packaging materials. Experts discussed migration of contaminant residues from food packaging, presented emerging analytical methods for safety evaluation, and highlighted the use of improved exposure assessment models and new packaging technologies. The workshop then focused on recycled packaging and sustainability. Experts also discussed application of recycled materials in food packaging, recycling processes, identification of contaminant residues from recycled packaging, and challenges in safety assessment of recycled materials. The workshop concluded with panel
discussions that highlighted the challenges and research gaps in food packaging. Overall, there is a need to better understand and define “contaminants in food packaging” for developing appropriate testing methods needed to establish the significance of the migration levels of these contaminants and conduct appropriate safety assessments in this rapidly evolving field.

**Efficacy of Antimicrobial Agents for Food Contact Applications: Biological Activity, Incorporation into Packaging, and Assessment Methods: A Review**


**Significance:** The safety, efficacy and incorporation techniques of antimicrobial agents used for active food packaging materials are reviewed.

Interest in the utilization of antimicrobial active packaging for food products has increased in recent years. Antimicrobial active packaging involves the incorporation of antimicrobial compounds into packaging materials, with the aim of maintaining or extending food quality and shelf life. Plant extracts, essential oils, organic acids, bacteriocins, inorganic substances, enzymes, and proteins are used as antimicrobial agents in active packaging. Evaluation of the antimicrobial activity of packaging materials using different methods has become a critical issue for both food safety and the commercial utilization of such packaging technology. This article reviews the different types of antimicrobial agents used for active food packaging materials, the main incorporation techniques, and the assessment methods used to examine the antimicrobial activity of packaging materials, taking into account their safety as food contact materials.

**Caffeine**

**Consumption of Coffee but Not of Other Caffeine-Containing Beverages Reduces the Risk of End-Stage Renal Disease in the Singapore Chinese Health Study**


**Significance:** This prospective study evaluated the relationships between caffeine-containing beverages and the risk of end-stage renal disease in a middle- and older-aged Chinese population.

**Background:** Cross-sectional studies suggest that coffee drinking is associated with better renal function. However, to our knowledge, no prospective study has examined its relation with the risk of end-stage renal disease (ESRD). **Objective:** We examined the relations between coffee, tea, soda, and total caffeine consumption and the risk of ESRD among middle-aged and older Chinese in Singapore. **Methods:** We used data from the Singapore Chinese Health Study, a prospective cohort of 63,257 men and women aged 45-74 y at recruitment from 1993 to 1998. Baseline information on the consumption of caffeinated coffee and other caffeinated beverages (tea and sodas), habitual diet, medical history, and lifestyle factors was obtained via in-person interviews. The standard serving size of 1 cup was assigned as 237 mL in the questionnaire. Incident ESRD cases were identified via linkage with the nationwide registry. We used multivariable Cox regression models to estimate HRs and 95% CIs of ESRD risk associated with the consumption of caffeinated beverages, with adjustment for potential confounders. **Results:** After a mean follow-up of 16.8 y, 1143 cohort subjects developed ESRD. Compared with those who drank coffee less than daily, the HR (95% CI) was 0.91 (0.79, 1.05) for those who drank 1 cup of coffee/d and 0.82 (0.71, 0.96) for those who drank ≥2 cups/d (P-trend = 0.012). When stratified by sex, this association was observed in men but not in women. Compared with those who drank less than daily, the HR (95% CI) for drinking ≥2 cups/d was 0.71 (0.57, 0.87) among men and 0.97 (0.78, 1.19) among women (P-interaction = 0.03). Conversely, intakes of tea, soda, or total caffeine were not associated with the risk of ESRD in multivariable models. **Conclusion:** The consumption of ≥2 cups of coffee/d may reduce the risk of ESRD in the general population, especially among men. This study was registered at [http://www.clinicaltrials.gov as NCT03356340](http://www.clinicaltrials.gov as NCT03356340).