January 2023

Food Safety Briefs

Risk Assessment

Textual Data Transformations Using Natural Language Processing for Risk Assessment

Mohammad Zaid Kamil, Mohammed Taleb-Berrouane, Faisal Khan, Paul Amyotte, Salim Ahmed. *Risk Anal.* 2023 Jan 22. doi: 10.1111/risa.14100. **Article link**

Significance: Textual data can be a vital learning resource for developing risk assessment methods. This work addresses the knowledge gap in extracting relevant features from textual data to develop cause-effect scenarios.

Underlying information about failure, including observations made in free text, can be a good source for understanding, analyzing, and extracting meaningful information for determining causation. The unstructured nature of natural language expression demands advanced methodology to identify its underlying features. There is no available solution to utilize unstructured data for risk assessment purposes. Due to the scarcity of relevant data, textual data can be a vital learning source for developing a risk assessment methodology. This work addresses the knowledge gap in extracting relevant features from textual data to develop cause-effect scenarios with minimal manual interpretation. This study applies natural language processing and text-mining techniques to extract features from past accident reports. The extracted features are transformed into parametric form with the help of fuzzy set theory and utilized in Bayesian networks as prior probabilities for risk assessment. An application of the proposed methodology is shown in microbiologically influenced corrosion-related incident reports available from the Pipeline and Hazardous Material Safety Administration database. In addition, the trained named entity recognition (NER) model is verified on eight incidents, showing a promising preliminary result for identifying all relevant features from textual data and demonstrating the robustness and applicability of the NER method. The proposed methodology can be used in domain-specific risk assessment to analyze, predict, and prevent future mishaps, ameliorating overall process safety.

Foodborne Pathogens

The Background Microbiota and Sanitization Agent Drive the Fate of *Listeria monocytogenes* in Multispecies Biofilms Formed on a Plasma-Polymerized Coating Applied on Stainless Steel

Paula Fernández-Gómez, Marcia Oliveira, José F Cobo-Díaz, Montserrat González-Raurich, Rodolfo Múgica-Vidal, Fernando Alba-Elías, Miguel Prieto, et. al. *Int J Food Microbiol.* 2023 Jan 2;386:110017. doi: 10.1016/j.ijfoodmicro.2022.110017. **Article link**

Significance: Though sodium hypochlorite was in general slightly less effective than peracetic acid immediately after application, it caused a stronger growth control of the naturally present *L. monocytogenes* on multispecies biofilms.

The present study evaluates the anti-biofilm activity of a coating applied with an atmospheric-pressure plasma jet system on AISI 316 stainless steel (SS) against multispecies biofilms containing *Listeria monocytogenes* (using background microbiota from three different meat industries) using culture-dependent and culture-independent approaches. Also, the disinfection effectiveness and biofilm evolution after sanitization with two food industry biocides were assessed. The anti-biofilm activity of the coating against *L. monocytogenes,* observed on mono-species biofilms ($p < 0.05$), was lost on the multispecies biofilms developed for 7 days at 12 °C ($p > 0.05$), with *L. monocytogenes* counts ranging from 5.5 ± 0.7 to 6.1 ± 0.5 CFU/cm2 on the uncoated SS and from 4.4 ± 0.2 to 6.4 ± 0.5 CFU/cm2 on the coated SS. The taxonomic composition of the formed biofilms was highly

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dependent on the industry but not affected by the artificial inoculation with *L. monocytogenes* and the nature of the surface (coated vs uncoated SS). When *L. monocytogenes* was artificially inoculated, its growth was partially controlled in the biofilms developed, with the magnitude of this effect being lower ($p < 0.05$ on coated SS) for the industry with the lowest taxonomy richness and diversity (3.8 ± 0.2 CFU/cm2), as compared the other two sampled industries (2.4 ± 0.4 and 1.6 ± 0.2 CFU/cm2). The 15-minute disinfection treatments with either sodium hypochlorite or peracetic acid at 0.5 % resulted in total viable and *L. monocytogenes* counts below the limit of detection in most cases, immediately after treatment. The subsequent incubation of the sanitized plates for another 7 days at 12 °C in fresh BHI media led to the development of biofilms with lower bacterial richness and alpha diversity, and higher beta diversity. Even though sodium hypochlorite was in general slightly less effective than peracetic acid immediately after application, it caused a stronger growth control ($p < 0.05$) of the naturally present *L. monocytogenes* on the multispecies biofilms developed. This finding highlights the importance of understanding the interspecific competitive relationships between the members of the background microbiota and *L. monocytogenes* for the long-term control of this pathogen in food processing facilities.

Foodborne Illness

Functionalized Screen-Printed Electrodes for the Thermal Detection of *Escherichia coli* in Dairy Products

Rocio Arreguin-Campos, Margaux Frigoli, Manlio Caldara, Robert D Crapnell, Alejandro Garcia-Miranda Ferrari, Craig E Banks, Thomas J Cleij, et. al *Food Chem*. 2023 Jan;404(Pt B):134653. doi: 10.1016/j.foodchem.2022.134653. **Article link**

Significance: A set of proposed thermal biosensor possesses the potential of becoming a tool for routine, on-site monitoring of *E. coli* in food safety applications.

Accurate and fast on-site detection of harmful microorganisms in food products is a key preventive step to avoid foodborne illness and product recall. In this study, screen-printed electrodes (SPEs) were functionalized via a facile strategy with surface imprinted polymers (SIPs). The SIP-coated SPEs were used in combination with the heat transfer method (HTM) for the real-time detection of *Escherichia coli*. The sensor was tested in buffer, with a reproducible and sensitive response that attained a limit of detection of 180 CFU/mL. Furthermore, selectivity was assessed by analyzing the sensor's response to *C. sakazakii*, *K. pneumoniae* and *S. aureus* as analogue strains. Finally, the device was successfully used for the detection of *E. coli* in spiked milk as proof-of-application, requiring no additional sample preparation. These results suggest the proposed thermal biosensor possesses the potential of becoming a tool for routine, on-site monitoring of *E. coli* in food safety applications.

Mycotoxins

Microbial Enzymes Involved in the Biotransformation of Major Mycotoxins

Tosin Victor Adegoke, Bolei Yang, Fuguo Xing, Xiaoyu Tian, Gang Wang, Bowen Tai, Peidong Si, et. al. *J Agric Food Chem*. 2022 Dec 27. doi: 10.1021/acs.jafc.2c06195. **Article link**

Significance: A new biotransformation method using whole microbial cells or isolated enzymes could be optimal for mitigating mycotoxins. Using specific enzymes may avoid the disadvantages of utilizing a full microbe, among other benefits.

Mycotoxins, the most researched biological toxins, can contaminate food and feed, resulting in severe health implications for humans and animals. Physical, chemical, and biological techniques are used to mitigate mycotoxin contamination. The biotransformation method using whole microbial cells or isolated enzymes is the best choice to mitigate mycotoxins. Using specific enzymes may avoid the disadvantages of utilizing a full microbe, such as accidental harm to the product's organoleptic characteristics and hazardous safety features. Moreover, the degradation rates of the isolated enzymes are higher than those of the whole-cell reactions, and they are substrate-specific. Their specificity is comprehensive and is shown at the positional and/or chiral center in many circumstances. Currently, only a few enzymes of microbial origin are commercially available. Therefore, there is a need to identify more novel enzymes of microbial origin that can mitigate mycotoxins. In this review, we conducted an in-depth summary of the microbial enzymes involved in the biotransformation of mycotoxins.

Heavy Metals

Evaluating the Impact of Heavy Metals on Antimicrobial Resistance in the Primary Food Production Environment: A Scoping Review

Elena Anedda, Maeve Louise Farrell, Dearbháile Morris, Catherine M Burgess. *Environ Pollut*. 2023 Jan 6;320:121035. doi: 10.1016/j.envpol.2023.121035. **Article link**

Significance: This reviews highlights a link between heavy metals and anti-microbial resistance in the primary food production environment.

Heavy metals are naturally occurring environmental compounds, which can influence antimicrobial resistance (AMR) dissemination. However, there is limited information on how heavy metals may act as a selective pressure on AMR in the primary food production environment. This review aims to examine the literature on this topic in order to identify knowledge gaps. A total of 73 studies, which met pre-established criteria, were included. These investigations were undertaken between 2008 and 2021, with a significant increase in the last three years. The majority of studies included were undertaken in China. Soil, water and manure were the most common samples analysed, and the sampling locations varied from areas with a natural presence of heavy metals, areas intentionally amended with heavy metals or manure, to areas close to industrial activity or mines. Fifty-four percent of the investigations focused on the analysis of four or more heavy metals, and copper and zinc were the metals most frequently analysed (n = 59, n = 49, respectively). The findings of this review highlight a link between heavy metals and AMR in the primary food production environment. Heavy metals impacted the abundance and dissemination of mobile genetic elements (MGEs) and antimicrobial resistance genes (ARGs), with MGEs also observed as playing a key role in the spread of ARGs and metal resistance genes (MRGs). Harmonization of methodologies used in future studies would increase the opportunity for comparison between studies. Further research is also required to broaden the availability of data at a global level. This review aims to examine the literature on this topic in order to identify knowledge gaps. A total of 73 studies, which met pre-established criteria, were included. These investigations were undertaken between 2008 and 2021, with a significant increase in the last three years. The majority of studies included were undertaken in China. Soil, water and manure were the most common samples analysed, and the sampling locations varied from areas with a natural presence of heavy metals, areas intentionally amended with heavy metals or manure, to areas close to industrial activity or mines. Fifty-four percent of the investigations focused on the analysis of four or more heavy metals, and copper and zinc were the metals most frequently analysed (n = 59, n = 49, respectively). The findings of this review highlight a link between heavy metals and AMR in the primary food production environment. Heavy metals impacted the abundance and dissemination of mobile genetic elements (MGEs) and antimicrobial resistance genes (ARGs), with MGEs also observed as playing a key role in the spread of ARGs and metal resistance genes (MRGs). Harmonization of methodologies used in future studies would increase the opportunity for comparison between studies. Further research is also required to broaden the availability of data at a global level.

Food Packaging

Biopolymer Food Packaging Films Incorporated with Essential Oils

Bingren Tian, Jiayue Liu, Wanzhexi Yang, Jian-Bo Wan. *J Agric Food Chem*. 2023 Jan 25;71(3):1325-1347. doi: 10.1021/acs.jafc.2c07409. **Article link**

Significance: Due to significant new research and advanced technologies, synthetic additives in packaging materials are being progressively replaced with natural substances such as essential oils.

Petroleum-based packaging materials are typically nonbiodegradable, which leads to significant adverse environmental and health issues. Therefore, developing novel efficient, biodegradable, and nontoxic food packaging film materials has attracted increasing attention from researchers. Due to significant research and advanced technology, synthetic additives in packaging materials are progressively replaced with natural substances such as essential oils (EOs). EOs demonstrate favorable antioxidant and antibacterial properties, which would be an economical and effective alternative to synthetic additives. This review summarized the possible antioxidant and antimicrobial mechanisms of various EOs. We analyzed the properties and performance of food packaging films based on various biopolymers incorporated with EOs. The prog-ress in intelligent packaging materials has been discussed as a prospect of food packaging materials. Finally, the current challenges regarding the practical application of EOs-containing biopolymer films in food packaging and areas of future research have been summarized.

Chemical Contaminants

The Contribution of Cacao Consumption to the Bioaccessible Dietary Cadmium Exposure in the Belgian Population

Ruth Vanderschueren, Jasmien Doevenspeck, Lieselot Goethals, Mirjana Andjelkovic, Nadia Waegeneers, Erik

Smolders. *Food Chem Toxicol*. 2023 Jan;172:113599. doi: 10.1016/j.fct.2023.113599. **Article link**

Significance: This study suggests that Cadmium intake from cacao consumption has been underestimated because of hidden cacao in non-chocolate food categories.

Since 2019, EU limits apply to cadmium (Cd) concentrations in cacao-derived food products. The dietary risk assessment leading to that regulation used consumption surveys aggregated to a limited number of chocolate product categories and did not consider differences in Cd bioaccessibility. Here, the cacao-related dietary Cd exposure in the Belgian population was estimated with higher resolution and accounting for bioaccessibility. A food frequency questionnaire and a 24-h recall (N = 2055) were set up for the Belgian population, in combination with ICP-MS analysis of a large subset of cacao-containing products (N = 349). Both the average chocolate consumption (28 g day-1) and the relative contribution of chocolate to the total dietary Cd exposure (7-9%) were higher than previously estimated for the Belgian population, probably because of some selection bias towards chocolate consumers in the cohort. The Cd bioaccessibility in chocolate products was a factor 5 (cacao powder) and 2 (dark chocolate) lower compared to wheat flour, suggesting lower bioavailability in chocolate than in wheat, which is a main contributor to dietary Cd. This study suggests that Cd intake from cacao consumption has been underestimated because of hidden cacao in non-chocolate food categories but, in contrast, may have overestimated the true exposure because of lower bioavailability compared to the main foodstuffs contributing to Cd exposure.

Caffeine

Urine Caffeine Metabolites are Positively Associated with Cognitive Performance in Older Adults: An Analysis of US National Health and Nutrition Examination Survey (NHANES) 2011 to 2014

Di Liu, Fengfei Xie, Nimei Zeng, Renfang Han, Deli Cao, Zengli Yu, Yun Wang, Zhongxiao Wan. *Nutr Res*. 2023 Jan;109:12-25. doi: 10.1016/j.nutres.2022.11.002. **Article link**

Significance: This study found a significant positive association between urine caffeine metabolites and cognitive performance in older adults, particularly for theophylline, paraxanthine and caffeine.

The aim of this study was to explore urine caffeine metabolites in relation to cognitive performance among 2011-2014 National Health and Nutrition Examination Survey participants aged ≥60 years. We hypothesized that urine caffeine metabolites were positively associated with cognition in older adults. Caffeine and 14 of its metabolites were quantified in urine by use of high-performance liquid chromatography-electrospray ionization-tandem quadruple mass spectrometry with stable isotope labeled internal standards. Cognitive assessment was based on scores from the word learning and recall modules. Participants were categorized based on the quartiles of caffeine and its metabolites level. The association between caffeine metabolites and each cognitive dimension was analyzed using multiple logistic regression analysis in adjusted models. Stratification analyses by gender were also performed. For CERAD test, there was a significant association between 1-methyluric acid (OR=0.62, 95% CI: 0.42 to 0.92), 7-methylxanthine(OR=0.49, 95% CI: 0.27 to 0.89), theophylline (OR=0.52, 95% CI: 0.29 to 0.92), as well as paraxanthine (OR=0.49, 95% CI: 0.27 to 0.88) and cognitive function. For animal fluency test, there was a positive association between theophylline (TP) (OR=0.44, 95% CI: 0.22 to 0.89) and cognitive function. The trend that the risk of low cognitive function decreased with increasing concentration of 1-methylxanthine (P trend=0.0229) was also observed. Furthermore, the same trend existed for 3-methylxanthine (p trend = 0.0375) in men. In conclusion, there was a significant positive association between urine caffeine metabolites and cognitive performance in older adults, particularly for theophylline, paraxanthine and caffeine; and the association might be dependent on gender.

Food Allergens

Intestinal Protein Uptake and IgE-Mediated Food Allergy

Anne-Sofie Ravn Ballegaard, Katrine Lindholm Bøgh. *Food Res Int*. 2023 Jan;163:112150. doi: 10.1016/j.foodres.2022.112150. **Article link**

Significance: Knowledge on factors affecting intestinal barrier functions and methods for the determination of their impact on protein uptake may be useful in future allergenicity assessments.

Food allergy is affecting 5-8% of young children and 2-4% of adults and seems to be increasing in prevalence. The cause of the increase in food allergy is largely unknown but proposed to be influenced by both environmental and lifestyle factors. Changes in intestinal barrier functions and increased uptake of dietary proteins have been suggested to have a great impact on food allergy. In this review, we aim to give an overview of the gastrointestinal digestion and intestinal barrier function and provide a more detailed description of intestinal protein uptake, including the various routes of epithelial transport, how it may be affected by both intrinsic and extrinsic factors, and the relation to food allergy.

Further, we give an overview of *in vitro*, *ex vivo* and *in vivo* techniques available for evaluation of intestinal protein uptake and gut permeability in general. Proteins are digested by gastric, pancreatic and integral brush border enzymes in order to allow for sufficient nutritional uptake. Absorption and transport of dietary proteins across the epithelial layer is known to be dependent on the physicochemical properties of the proteins and their digestion fragments themselves, such as size, solubility and aggregation status. It is believed, that the greater an amount of intact protein or larger peptide fragments that is transported through the epithelial layer, and thus encountered by the mucosal immune system in the gut, the greater is the risk of inducing an adverse allergic response. Proteins may be absorbed across the epithelial barrier by means of various mechanisms, and studies have shown that a transcellular facilitated transport route unique for food allergic individuals are at play for transport of allergens, and that upon mediator release from mast cells an enhanced allergen transport via the paracellular route occurs. This is in contrast to healthy individuals where transcytosis through the enterocytes is the main route of protein uptake. Thus, knowledge on factors affecting intestinal barrier functions and methods for the determination of their impact on protein uptake may be useful in future allergenicity assessments and for development of future preventive and treatment strategies.

Emerging Science Areas

Emerging Areas Food Safety

Accelerating the Detection of Bacteria in Food Using Artificial Intelligence and Optical Imaging

Luyao Ma, Jiyoon Yi, Nicharee Wisuthiphaet, Mason Earles, Nitin Nitin. *Appl Environ Microbiol*. 2023 Jan 31;89(1):e0182822. doi: 10.1128/aem.01828-22. **Article link**

Significance: This study combined artificial intelligence and optical imaging to detect bacteria at the microcolony stage within 3 hours of inoculation.

In assessing food microbial safety, the presence of *Escherichia coli* is a critical indicator of fecal contamination. However, conventional detection methods require the isolation of bacterial macrocolonies for biochemical or genetic characterization, which takes a few days and is labor-intensive. In this study, we show that the real-time object detection and classification algorithm You Only Look Once version 4 (YOLOv4) can accurately identify the presence of *E. coli* at the microcolony stage after a 3-h cultivation. Integrating with phase-contrast microscopic imaging, YOLOv4 discriminated *E. coli* from seven other common foodborne bacterial species with an average precision of 94%. This approach also enabled the rapid quantification of *E. coli* concentrations over 3 orders of magnitude with an R2 of 0.995. For romaine lettuce spiked with *E. coli* (10 to 103 CFU/g), the trained YOLOv4 detector had a false-negative rate of less than 10%. This approach accelerates analysis and avoids manual result determination, which has the potential to be applied as a rapid and user-friendly bacterial sensing approach in food industries. IMPORTANCE A simple, cost-effective, and rapid method is desired to identify potential pathogen contamination in food products and thus prevent foodborne illnesses and outbreaks. This study combined artificial intelligence (AI) and optical imaging to detect bacteria at the microcolony stage within 3 h of inoculation. This approach eliminates the need for time-consuming culture-based colony isolation and resource-intensive molecular approaches for bacterial identification. The approach developed in this study is broadly applicable for the identification of diverse bacterial species. In addition, this approach can be implemented in resource-limited areas, as it does not require expensive instruments and significantly trained human resources. This AI-assisted detection not only achieves high accuracy in bacterial classification but also provides the potential for automated bacterial detection, reducing labor workloads in food industries, environmental monitoring, and clinical settings.

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