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Dike Ukuku,
Agricultural Research Service (USDA),
United States

*CORRESPONDENCE
Shalini Gaur Rudra
shalinigaur@iari.res.in

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Editorial: Food storage, spoilage and shelf life: Recent developments and insights

Shalini Gaur Rudra[1]*, Santanu Basu[2] and Anindya Chanda[3]

[1]Division of Food Science and Postharvest Technology, Indian Agricultural Research Institute, New Delhi, India, [2]Department of Molecular Sciences, Swedish University of Agricultural Sciences, Uppsala, Sweden, [3]Mycologics LLC, Durham, NC, United States

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Editorial on the Research Topic
Food storage, spoilage and shelf life: Recent developments and insights

The past few years have witnessed high levels of food production, processing and preservation due to advancements in crop production and protection. However, with global climate change, the pandemic, and the hindered food supply chain influenced by the ongoing geopolitical events, access to safe foods has become increasingly challenging. Besides, the pace of development in food storage has not been at par, leading to global problems of food spoilage and waste generation at various points of the supply chain and even at the consumers' end. Furthermore, with a rapidly increasing global population expected to cross 8.5 billion by 2030, there is a pressing need to reduce the amount of per capita global food waste at the retail and consumer levels by at least 50% to meet the Target 12.3 of the Sustainable Development Goals[1].

Improved storage conditions and technologies for combating foodborne pathogens will also lead to enhanced food safety. Consumption of unsafe foods amounts to 600 million reported foodborne illnesses and 420,000 deaths worldwide every year, with 30% of foodborne deaths occurring among children under 5 (Lee and Yoon, 2021). An estimated 33 million years[2] of healthy lives are lost because of eating unsafe food globally each year, although according to the WHO, this number is likely an under-estimation. Recent examples of foodborne illnesses include a multistate outbreak of *Salmonella* infections in the United States (https://www.miamiherald.com/news/recalls/article261667272.html), the Norovirus poisoning of oysters[3] (>100 cases) in Canada, the

1 https://www.unep.org/thinkeatsave/about/sdg-123-food-waste-index

2 https://www.who.int/activities/estimating-the-burden-of-foodborne-diseases

3 https://www.foodsafetynews.com/2022/04/fda-says-reports-nearing-450-in-outbreak-associated-with-lucky-charms-cereal/

100 illnesses from *Staphylococcus aureus* exposure at the Coachella festival[4] in California, the *Salmonella* outbreak in Finland[5] that affected more than 700 people, and the 70 cases from Shigella toxin exposure in India[6], including the death of a teenager. These examples are a grim reminder of the importance of proper food preparation, storage and rapid detection of food pathogens.

The objective of floating the Research Topic on Food storage, spoilage, and shelf life was to compile the advances in research toward preventing food spoilage, enhancing shelf life, and monitoring conditions during storage. The topic saw a tremendous response from researchers, with twenty-seven submissions and seventeen accepted articles contributed by sixty-seven authors worldwide. The total views numbering > 37,500 show the keen interest of researchers in this area.

The identification and distinction of pathogens from their close relatives pose a significant challenge to researchers and food safety professionals[7]. False detection of pathogens has enormous economic and legal implications, while missing out on the pathogens can lead to disease or even death. Olajide et al. from Canada identified the presence of fengycin operon in *B. paralicheniformis* through MADI-TOF. These two genetic markers (FenC and FenD) will help in reliable and quick differentiation of *Bacillus* species adequately, which cause spoilage in foods, including dairy. Bouju-Albert et al. developed a rapid and accurate *rpoC*-PMA-qPCR method to detect *Brochothrix thermosphacta*, a major food spoilage bacteria responsible for off-odors production in beef and seafood. This is the first report on the use of qPCR to quantify *B. thermosphacta*, along with the use of a viability dye (PMA or PMAxx) and the targeting of a single-copy gene (*rpoC* or *rpoB*).They could efficiently discriminate between live and dead cells and validated the test on industrially processed cold-smoked salmon filets. Their method could specifically and quickly enumerate *B. thermosphacta* within 3–4 h compared to 48 h for the STAA culture method.

Li et al. used high-throughput sequencing of the V3–V4 region of the 16S rRNA gene to study the dynamics, diversity, interaction, and succession of five food spoilage bacteria after inoculating sterilized smoked bacon with their culture. *Serratia liquefaciens*, *C. maltaromaticum*, and *L. mesenteroides* were identified as more competitive species over others. Similarly, Han et al. generated helpful information for optimizing sausage storage conditions after studying the microbiota non-volatile metabolites in a model sausage after storage at 20°C for up to 12 days. Such a study on sausage samples exposed to an open environment during production, marketing, and distribution and characterization of quality and microbiota changes is rare and has seen > 1,000 views. Correct identification of the dominant species and their dynamism plays a key role in determining the strategies for preservation and prevention of disease outbreak during storage. Therefore studies like this would help improve the shelf life of meat products.

A similar study was conducted by Wei et al. to isolate and identify the dominant microorganism in *Flammulina velutipes* fruiting bodies using morphological examination and high-throughput sequencing. The kinetic models for describing the growth of predominant spoilage microorganism *L. lactis* can be used by regulatory agencies and food processors for conducting risk assessments and predicting the shelf-life of *Flammulina velutipes* fruiting bodies.

Prabhakar et al. studied the dynamic behavior of fish volatiles and the growth of microbes in stored Rohu fish through mathematical modeling. The findings of this study would help predict the freshness of rohu fish, and aid design and understand cold chain logistics for seafood.

Wang and Xie inoculated *Acinetobacter johnsonii*, *Shewanella putrefaciens*, and their co-cultures in bigeye tuna during cold storage and monitored quality changes and microbial dynamics. Trapped water, protein degradation, and lipid oxidation studies provide data for understanding the spoilage mechanism of co-cultures and enable estimation of aquatic food quality and shelf-life. Pathogens and spoilage microbes can enter at any point of food chain. Usually, toxin-producing strains of *B. cereus* originate from soil, water, and plants. But even packaging material can emerge as source of pathogen. From Austria, Schmid et al. have explored the presence and possible spoilage potential of *B. cereus* from packaging material. The first such study in this area showed that although a variety of *B. cereus* group strains can be found in packaging material, significant amounts of highly virulent strains and cereulide-producing strains are not present.

Milk spoilage due to spore-producing psychrotolerant microorganisms is an emerging problem since these spores can even tolerate pasteurization temperatures. Enayaty-Ahangar et al. have provided novel decision support tools to aid individual processors in identifying a suitable approach to achieving desired milk shelf-life as per their specific production conditions along with the motivation for the shelf-life extension. Such decision support systems can not only help in improving distribution efficiencies and ensure safe, long-lasting, high-quality dairy products for consumers, but also serve as guideline for other food chains.

The recent trend for preference for preservative-free and clean labels has seen developments in chemical-free

4 https://www.foodsafetynews.com/2022/05/staph-blamed-for-foodborne-illness-outbreak-among-coachella-bus-drivers/

5 https://www.foodsafetynews.com/2022/05/large-salmonella-outbreak-dominates-finnish-figures/

6 https://indianexpress.com/article/india/kerala/shigella-food-poisoning-girl-died-shawarma-kerala-health-dept-7899820/

7 https://www.who.int/news-room/fact-sheets/detail/food-safety#:$\sim$:text=An%20estimated%20600%20million%20%E2%80%93%20almost,healthy%20life%20years%20(DALYs)

food safety alternatives. Efficient packaging protects from contaminants. Modern packages have evolved to not only aid in preventing spoilage but indicate the state of quality while being environmentally friendly. Ahari and Soufiani have reviewed the latest developments in the field of packaging. Antimicrobial packaging can play an essential role in reducing the risk of pathogen contamination and improving foods' quality and shelf life. Various inorganic nanoparticles (silver, copper, gold, metal oxides) help induce antimicrobial attributes in packaging materials. They have discussed the issues related to degradation, indicator and scavenger functions of modern smart packages. Anvar et al. have reviewed the developments in these new antimicrobials for the improved shelf life of food products. In addition, they have provided advisory on food handling in COVID-19 scenario. The use of nanoparticles for intelligent food packages has also been reviewed.

On similar lines, scientists are working toward finding safer approaches for pathogen management during storage. Green postharvest solutions protect not just the fresh produce but also humankind. Ring rot spoilage of apples by *Botryosphaeria dothidea* is a major postharvest disease in bag-free cultivated apples. Plant activator butylated hydroxytoluene can emerge as an alternative to synthetic pesticides. Huang et al. reported that BHT confers resistance against *B. dothidea* in apple fruits, possibly by enhancing defensive enzyme activities and activating the salicylic acid signaling pathway. Alongside facing biotic challenges, fruits usually travel miles to reach the consumer. During this journey, mechanical damage in the form of bruises can lead to faster ripening, internal browning, and quality losses. Bruising can lead to increased surface area for microbial attachment, and survival due to nutrient leakage. The effect of such various drop impact levels, storage temperature, and storage duration on the quality of pears was studied by Pathare and Dairi. The findings of their study can help understand the mechanism of bruising and determine ways to reduce it.

Implementing food safety and sustainability through food safety entrepreneurship poses numerous challenges. In their research contribution, Varyvoda et al. have presented food safety solutions for Nepal, Senegal, and Ethiopia, including diversification, use of underutilized food sources, marrying traditional knowledge with innovations and use of digital technology. They suggest that in scenarios where the local context of business operations influences food safety practices, the intervention programs should consider their influence and consequence for effective implementation in the field. Among such underutilized food sources are millets, sorghum, and amaranth. These climate-resilient crops can provide sustainable solutions for production and nutrition. Geisen et al. demonstrated that while millets appear similar to the human eye, there is a considerable variation in mechanical properties like bulk density, color, porosity, etc. They have proposed a methodology for their physical characterization and highlighted the need for focused breeding programs and product development based on the specific attribute of each millet grain.

In practice, sustainable grain storage systems offer numerous challenges in sub-tropical climates like that of India. Kumar et al. have documented the storage management practices of wheat in the Food Corporation of India (handling > 70 million tons of cereals annually) in their warehouse system and quantified the storage losses based on field study. They have reported that adopting proper storage management practices for wheat in warehouse storage has brought the level of storage losses (0.3% in 3 years) equivalent to silo storage.

Conversion of agricultural waste to safe animal feed is another dimension of food sustainability. He et al. have studied the effectiveness of two lactic acid bacterial strains for ensiling sweet potato vine and peanut straw. Effective and safe animal feed translates to safety for humans also, especially in the wake of zoonotic disease spread like COVID-19.

The research contributions to this topic showcased the multiple dimensions of food safety and sustainability with élan. For example, the use of genetic markers, mathematical modeling, non-synthetic chemicals, nanomaterials, packaging aids, decision support systems, etc. to identify and contain food spoilage agents, along with other considerations like reducing mechanical damage, alternative food sources, on-field efficient storage practices, all pave the way to safe and sustainable food environment for future generations.

Author contributions

All authors contributed to the review of manuscripts and preparation of this editorial. All authors contributed to the article and approved the submitted version.

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Conflict of interest

Author AC was employed by Mycologics LLC.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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