# Electromagnetic imaging and sensing for food quality and safety assessment [Guest Editorial]

GUEST EDITORIAL

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# Electromagnetic Imaging and Sensing for Food Quality and Safety Assessment

Ensuring food quality and safety has broad-reaching health and economic impacts. In the broadest sense, food safety refers not only to whether the food we eat is safe for consumption but also to the safeguarding of the worldwide supply chain, from the source of the food to when it reaches our table. This includes safeguarding stored and packaged food items from spoilage and foodborne illnesses. According to the Food and Agriculture Organization, unsafe food is a threat to human health and economies globally because of the approximately 600 million annual cases of foodborne illnesses (http://www.fao.org/food-safety/background/en/). Spoilage of stored and packaged food also has a large economic impact. Therefore, ensuring food safety is a public health priority that has to be synergistically addressed by policy makers and manufacturers as well as by the scientific community tasked with developing new technological solutions to improve food safety and protect public health.

In particular, research into the development of suitable sensors and control devices, coupled with smart algorithms, for the monitoring of food to enhance safety management along the entire food chain will play a major role in the forthcoming years. On the other hand, as stakeholders in food safety know, there is no "silver bullet" technology: Attention must be focused on combining multiple sensing and imaging technologies to cope with such a complex problem and minimize or eliminate the overall risk of foodborne illnesses and incidents.

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In this framework, electromagnetic (EM) sensing and imaging technologies can bring significant contributions to improve the detection of contaminants and food adulterations as well as monitoring food quality indices. The physical basis for EM sensing applications in this field relies on a twofold concept. First, most of the characteristics of food depend on water content, which ultimately affects its quality and of course has an impact on the EM properties of food. In addition, the EM properties of (biological and nonbiological) contaminants are usually different from those of unaltered food. Second, EM waves provide a noninvasive, possibly contactless tool for sensing the changes occurring in the surrounding environment as well as enabling remote access of such a piece of information. In doing so, EM technologies can complement with other technologies (e.g., X-ray or infrared) for monitoring chemical-based sensing platforms, building up hybrid approaches that can provide a silver lining for the food safety industry.

The goal of this special issue is to present to the antennas and propagation community some of the emerging research activities on the application of EM-based technologies in such a societally relevant topic. Six contributions are gathered in this issue, addressing food industry applications as different as sensing food quality and food spoilage indicators and monitoring food items to detect contaminants. From a technological point of view, the presented contributions cover the two main applications of EM sensing to food, that is, imaging for monitoring purposes and sensing

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with smart tags. Moreover, the described technologies allow the appreciation of one of the unique features of EM technologies, the possibility of exploiting different portions of the EM spectrum, from microwaves to millimeter-waves (mm-waves) up to optical frequencies, to cope with specific tasks.

The first article of the special issue, authored by J.A. Tobón Vásquez et al., proposes the use of microwave imaging technology to noninvasively monitor packaged food items moving along the production chain, exploiting the differences in dielectric properties between food and possible contaminants. In this respect, the challenge is to properly trade off acquisition speed with the need for gathering enough data to perform the imaging task by identifying proper measurement strategies and processing tools. A new EM imaging technology to monitor the health of stored grain is presented by J. LoVetri et al. Almost all grain commodities, such as corn, wheat, and rice, are stored immediately after harvest for time spans of days to years. This contribution shows how the spoilage of these stored commodities can be monitored by 3D imaging the complex valued permittivity of the grain using arrays of radio-frequency (RF) transmitter/receivers installed on the walls of the grain bin. The permittivity is related to the physiological health of the grain, and the goal is early detection of spoilage.

F. Zidane et al. explore the capability of a machine learning method, the support vector machines, to sort out healthy from damaged fruits for different varieties of apples and peaches from the analysis of mm-wave and low-THz measurements of the relevant scattered fields. F. Becker et al. present a review of different approaches to food inspection, with a particular attention to food adulteration. They also outline the potential of different sensor systems operated in the high-frequency part of the EM spectrum (from visible to terahertz frequencies).

In the contribution by C. Occhiuzzi et al., RF identification intelligent sensors for packaged tropical fruits are adopted to evaluate the fruit's state of ripeness. This low-cost EM sensor/label technology, coupled with automatic classification tools, is shown to be capable of recognizing the ripening levels of the packaged fruits with a high level of accuracy (higher than 85%). It also opens the door to adapting and expanding the technology to other packaged food applications.

Finally, the article by R. Raju et al. provides an overview of current developments in near-field and ultrahigh frequency (UHF) wireless passive sensors for monitoring food quality indices and food spoilage indicators. Solutions based on coupled-coil resonator and UHF chipless sensors with application to bacterial-count detection, volatile gas concentration, humidity, and pH monitoring are described.

We thank all the authors who have contributed to this special issue for providing high-quality articles as well as the reviewers who have thoroughly assessed the articles, thereby raising the scientific level of this work. We hope the readers will enjoy the issue and that it will inspire further research activities in such a societally relevant topic.

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