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Technological Innovations Against Future Pandemics with Novel Strategies for Food Safety

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Abstract

The protection of food safety has been a global concern, especially in light of potential future pandemics. Consequently, food safety issues have been increasingly emerging. Strategies for designing customer experience, such as customer listening strategies should be continuously enriched with innovations in products and services. Nonthermal technologies such as nanotechnology, cold plasma, and ozone applications can be considered and applied to ensure food safety. These are alternative methods for treating virus-contaminated food package surfaces. Electrochemical, optical biosensors, and a combination of nanomaterials, nanomaterials-integrated biosensing approach are promising for fast detection of future zoonotic viruses. These developments will lead to the detection of new zoonotic viruses or variants.

Keywords: Pandemi, nanomaterials,food packaging, biosensor, virus

1. Introduction

Understanding food safety hazards risk is necessary to avoid virus transmission in the food supply chain since there is always a risk of zoonotic virus-based outbreaks (Lu et al., 2021). For zoonotic viruses, food and food packaging materials may be potential long-distance carriers (Ayşen, 2022). Because viruses can be found to remain stable on food surfaces or, food contact surfaces. For instance, after COVID-19 break new variants turned out such as Delta (Who, 2024). New variants are also concern for food safety. For instance, recently it was proved that biofilms could be a reservoir for SARS-CoV-2 Delta variant to spread it throughout meat packaging plants [Featherstone et al., 2024). Therefore, more attention needs to be given to increase the preparedness for pandemic scenarios by the food industry (Li et al., 2021 and Dai et al., 2023)

Zoonotic viruses may transmit through respiration, contact during the production, processing, storage, transportation, and retail of food products (Zhang et al., 2022). Monkeypox virus is one of the examples after the COVID-19 outbreak. On 14th August 2024, WHO declared monkeypox outbreak a public health emergency of international concern (Who,2024). While there isn't enough data to measure the risk of monkeypox virus transmission through food, bushmeat is suspected to be a potential source. An infected food handler could contaminate

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food through contact with dirty hands, especially if they have lesions, or due to poor hygiene practices. Consequently, monkeypox might stay viable in contaminated food that kept in cold storage and heat treatment may inactivate the virus in food (Chaix et al.,2022).

West Nile is another zoonotic virus which primary hosts are typically wild birds. Species such as sparrows, crows, ravens, and some waterfowl play a significant role in the spread of West Nile virus. Mosquitoes acquire the virus by feeding on the blood of these infected birds and then transmit it to humans and other animals. Riverbanks, puddles formed by rainwater on the ground and rocks, swamps, melted snow waters, and artificial water accumulations are breeding grounds for mosquitoes that transmit the disease (Sağlık bakanlığı, 2022).

According to these concerns more efforts should be undertaken to fight against future zoonotic viruses. In this regard, nonthermal technologies such as nanotechnology, ozone application, and irradiation can also provide promising opportunities (Karuppaiah et al., 2023).

This mini review summarize recent innovative practices in food industry, consumer behaviours, biosensing approaches to detect zoonotic viruses, and offer suggestions for future pandemic situations.

2. Practices Against Future Outbreaks

In a recent survey study, it was stated that, there is a decline in the food safety awareness and practices among consumers (Wang et al., 2024). This leads to a higher perceived frequency new outbreaks attributed to inappropriate food processing. There is a need for government intervention to heighten consumer awareness of food safety, especially for the lower-income, elderly, and non-educated groups who may have less knowledge about food safety practices. Educating these people with some activities is important to mitigate the adverse consequences of unsafe food handling.

On the other hand, consumer habits headed towards healthier foods, vegan meat products, cultured meat, and online sales (Loh et al., 2021 and Ayseli et al., 2024). For instance, improvement in diet quality in Mediterranean countries, and Canada was observed (Mignogna et al., 2022). These approaches can help to decrease the zoonotic transmission risks and ensure food safety.

Restaurant managers should be attentive to customers' needs and aim to provide a high customer experience. Innovations in cuisine and home delivery are essential to meet evolving customer expectations. (Ayseli et al., 2024 and Bonfanti et al.,2023). Adopting new food preparation techniques or new services is crucial for customer experience management. The experiential delivery service can be further enhanced in future pandemics. The physical ambiance is vital for Michelin-starred restaurants as it offers a sense of exclusivity that might be lacking in home delivery. Developing strategies for delivering a luxurious gastronomic experience at home ensures that customers can still appreciate the experiential value of their purchase, even outside the upscale restaurant setting (Bonfanti et al., 2023).

Information about safety procedures implemented in the restaurant should be communicated to target customers on media platforms. These practices are expected to boost confidence in restaurant dining (Arriaga-Lorenzo et al., 2022).

3. Trends in Food Technology Applications and Food Packaging Materials

3.1 Application of Nonthermal Treatments

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Ready-to-eat food as well as packaged food products should not be ignored as potential vehicles for virus transmission. During COVID-19 pandemic slaughterhouses and meat processing factories have already been faced with a series of outbreaks (Arriaga-Lorenzo et al., 2022 and Matthews, 2020). Furthermore, reports are claiming the stability of SARS-CoV-2 on food products. SAR-CoV-2 could remain viable on salmon at 25 C° and 4 C° for 2 and 8 days respecitvely (Kulawik and Kumar Tiwari 2019). Possible survival on meat and meat-absorbed materials was confirmed by other researchers (Featherstone et al, 2022 and Dai et al 2022). Experimental inoculation of cucumber and lettuce with human COV-229E indicated that human-CoV-229E remains infectious on their surface for 72h (Blondin-Brosseau et al., 2021).

Non-thermal techniques such as ozone applications and UV-based technologies are promising emerging methods for inactivation (Guesmi et.al,2022 and Mortazavi et.al, 2022). New studies are necessary to determine the effects of novel techniques on zoonotic viruses or future foodborne viruses. For instance, ozone could react with the cysteine-rich domain of SARS-COV-2 spike protein and decrease the interaction between CoV and host cells; which decline the infectivity (Criscuolo et al., 2021 and Yao et al., 2020). studied the effect of humidity, temperature, and ozone levels on survival of SARS-CoV-2 and found that higher ozone level (95 μg m^{-3}) decreased spreadness. So, the use of ozone generators in risky environments could be a potential strategy for elimination (Masotti et al., 2020). In this sense, ozonated air may be used to disinfect bulk food shipments which may be virus attachment points.

Irradiation by short-wavelength UV light is another alternative method for inactive zoonotic viruses on solid surfaces like glass. It has been stated that employing 1 min a 275 nm UV-C LED is capable of inactivating 99.9% of SARS-CoV-2 (Lu et al, 2021 and Trivellin et al., 2021 and Biasin et al., 2021) reported that UVC rays are more effective compared to microwave and gamma probably due to SARS-CoV-2 dimensions and genome (Farahmandfar et.al, 2021). E-beam irradiation could be also an efficient treatment inside and outside surfaces of cold chain foods to reduce zoonotic virus contamination. (Luo et al., 2023) completely inactivated the porcine epidemic diarrhea virus and porcine transmissible gastroenteritis viruses, with the treatment of 4–6 kGy e-beam irradiation (Wang et al., 2022) used e-beam irradiation to sterilize plastic and filter paper units under cold-chain temperatures.

As one of the other non-thermal treatments, cold plasma application exhibits great potential to eliminate SARS-CoV-2, since it does not cause secondary pollution (Qin et al., 2021 and Vozzi et al., 2021 **)**. It has been proven that cold plasma may fragment the viral capsid protein and damage the RNA of SARS-CoV-2 (Wang et al., 2022 and Guo et al., 2022 and Zhang et al., 2021) have indicated that cold-plasma-treated air was able to inactivate a pseudovirus with SARS-CoV 2S protein (Capelli et al., 2022) Metin girmek için buraya tıklayın veya dokunun.used surface plasma device to decontaminate fresh-cut apple packages inoculated with SARS-CoV-2 RNA extract and stated that 10 minutes of exposure was enough to eliminate the viral RNA from the polyethylene terephthalate and polypropylene film materials. Researchers used click chemistry to attach the angiotensin-converting enzyme 2 protein, which serves as the receptor for SARS-CoV-2, to microalgae. This microrobot successfully eliminated SARS-CoV-2 from wastewater (Huang et al., 2022). Consequently, there is growing interest in developing analytical protocols for detecting viruses in sewage systems (Farahmandfar et al., 2021).

Reported studies indicate that other nonthermal methods (Vijayan et al., 2021 and Zhou et al., 2022) can be effective in avoiding transmission and infections on food contact surfaces and nanotechnology applications, high hydrostatic pressure, pulsed electric field, and their possible

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combination with novel technologies for stronger elimination should investigated. There still research is required for the development of new approaches to inactivate zoonotic viruses.

3.2 Biobased materials and novel detection methods

Biosensors can be alternative for the detection of viruses (Sadak et al., 2022) Since they overcome the limitations of standard techniques they have become an alternative for large-scale testing. Enzyme-based sensors are commercially electrochemical biosensors and can be modified with the advancement of nanomaterials for better analytical sensitivity, and stability at reduced costs of testing (Zhang et al., 2022). Electrochemical methods such as electrochemical impedance spectroscopy, voltammetry, amperometry, and potentiometry are also promising Karuppaiah et al., 2023).

Nanomaterial-based biosensors are other ideal alternatives to detect zoonotic viruses. (Zhang et. al 2022) developed a low-cost commercial interdigitated microelectrode-based sensor for salmon, scallops, and a packing bag for frozen meat, to recognize the trace S-protein. To construct highly selective and sensitive aptasensors to detect zoonotic viruses aptamers can be also combined with surface plasmon resonance, fluorescence, electrochemical techniques, nanopores Cas (Chen et al., 2021 and Zhang et. al., 2022).

Recent advancements in the CRISPR/Cas, called as emerging clustered regularly interspaced short palindromic repeats, system-based biosensing technology are attracting attention. These systems can be integrated with portable devices such as smartphones, nanopores, lateral flow assays, microfluidic chips developed a CRISPR/Cas12a system on spiked frozen shrimp to test SARS-CoV-2 in shrimp samples. The fluorescence results are visually detected by an UV lamp. Quantum dots and graphene nanomaterials have been used in CRISPR/Cas based biosensors. Therefore, nanomaterials with enzyme activity or fluorescent nanodiamonds still need to be further explored (Maddali et al., 2021) Portable nucleic acid sensors (W. Zhang et al., 2022) and optical biosensors have been also reported as promising devices in the literature (Rabiee et al., 2022).Spectroscopic detection methods proteomics can offer a robust option to detect virus in food products. Mass spectroscopy supports the detection of this virus at the surfaces of foods, and wastewater. Therefore, proteomics and mass spectrometry may play a role in the future possible outbreaks (Qian et al., 2023 and Bojórquez-Velázquez et al., 2022).

Above mentioned studies shows that these novel biosensors with nanomaterials such as nanobiosensor systems and novel spectrometric platforms will lead to efficient detection of future possible zoonotic viruses with high accuracy.

4. Challenges

Detecting zoonotic viruses using sensors is challenging due to the complexity of food products, which may influence sensor performance. Therefore, proper sampling and handling is crucial. Surface plasmon resonances aptasensors have low limit of detection but they are limited by their poor repeatability. Since their responses are influenced easily, optical sensors may not effectively determine small analytes because of weak signals. Other drawbacks of electrochemical sensors are their reduced accuracy and stability with repeated usage and analysis costs. Limited information is available regarding the real-time application in food. The absence of cohesive strategies presents challenge for service providers, stakeholders, policymakers, and governments in improving food supply chains (Gharibzahedi et al., 2024).

5. Conclusion

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Many lessons learned after COVID-19 outbreak regarding future preventive measures for food safety. A new model of trade regulations must be developed for strict application of hygiene measures at all stages of food processing. Touchable items in food factories or food markets including, knives, chopping boards, scales, and calculators are concerning. Cold chain management practices can be improved by focusing on the analysis of requirements to predict transmission risk. Non-thermal technologies will provide direction for future viral pandemics regarding food safety processing, transport, and handling strategies. Novel biosensing methods should be further explored for the detection of zoonotic viruses. There is a demand for biosensors for early viral detection. Future electrochemical detection systems will be required to detect mutations and variants using associated biorecognition elements. Nanomaterials-based biosensors can be advantageous as an alternate tool for detecting viruses. To better prepare for future outbreaks, the food industry needs to adopt affordable, portable, and reusable biosensing tools for accurate diagnosis.

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