Review of Contemporary Philosophy
ISSN: 1841-5261, e-ISSN: 2471-089X
Vol 22 (1), 2023
Pp 3408 -3416

Advances in the Epidemiology of Foodborne Illnesses: A Comprehensive Review of Detection Methods, Pathogen Dynamics, and Public Health Implications

[1]-Allami Essa Wasly,[2]- Abdulaziz Hassan Ahmed Thubab,[3]-Abdulrahim Wali Zailai,[4]-Wasif Saleem Salamah Alolasi,[5]- Hussain Abed Abdullah Alamri,[6]-Musab Ali Mohammed Ayoub,[7]- Abdulaziz Omar Hassan Qaysi,[8]-Mohammed Ali Abdul Hadi Al-Ghamdi,[9]- Yasir Jubran Mousa Ayyashi,[10]-Basem Yahya Akkam,[11]-Fayez Saleh Mohammad Alghamdi,[12]-Mutab Mohsen Hamdan Al-Anazi,[13]-Raed Abdullah Alzmea,[14]-Hamdi Abdulrahman Mustantq,[15]-Abdullah Mohammed Yahya Moatabi

1. Ksa, Ministry Of Health, King Abdullah Airport Health Monitoring Center
2. Ksa, Ministry Of Health, Batat Phc
3. Ksa, Ministry Of Health, King Abdullah Airport Health Monitoring Center
4. Ksa, Ministry Of Health, Jeddah
5. Ksa, Ministry Of Health, King Abdullah Port Health Monitoring Center Rabigh
6. Ksa, Ministry Of Health, Aljowa Phcc
7. Ksa, Ministry Of Health, Al-Makhwah General Hospital
8. Ksa, Ministry Of Health, Al-Makhwah General Hospital
9. Ksa, Ministry Of Health, Al-Makhwah2 Phcc
10. Ksa, Ministry Of Health
11. Ksa, Ministry Of Health, Jafen Phcc
12. Ksa, Ministry Of Health, National Guard
13. Ksa, Ministry Of Health
14. Ksa, Ministry Of Health, Adham General Hospital
15. Ksa, Ministry Of Health, Environmental And Occupational Health Management

Abstract

Background: Foodborne illnesses remain a critical public health issue, with pathogens causing millions of infections and thousands of deaths annually. The World Health Organization estimates that foodborne diseases lead to approximately 23 million illnesses and 5,000 fatalities each year in Europe alone. This review examines recent advances in the epidemiology of foodborne pathogens, highlighting the impact of factors such as food safety practices, environmental sanitation, and climate change on disease transmission.

Methods: We conducted a comprehensive analysis of both traditional and innovative detection methods for foodborne pathogens, including culture-based techniques, biochemical assays, immunological methods, and advanced biosensor technologies. Through a systematic review of literature from peer-reviewed sources, we identified significant trends in pathogen prevalence and detection efficacy.

Results: Results indicate that traditional methods, while reliable, are often time-consuming and labor-intensive, with culture-based techniques requiring up to several days for confirmation. In contrast, newer biosensor technologies and molecular diagnostics, including CRISPR-Cas systems, offer rapid detection with heightened sensitivity and specificity, allowing for timely intervention in food safety management.

Conclusion: While significant progress has been made in the detection and understanding of foodborne pathogens, challenges remain in the implementation of these advanced methods in industrial settings. Future research should focus on optimizing detection techniques to ensure rapid, accurate identification of pathogens, thus enhancing food safety and public health outcomes.

Keywords: Foodborne Illnesses, Pathogen Detection, Epidemiology, Biosensors, Public Health

Received: 07 october 2023 **Revised:** 22 November 2023 **Accepted:** 06 December 2023

1. Introduction

Food safety safeguards consumer health against foodborne diseases. Several critical elements, such as microbiological, chemical, and nutritional alterations, biological variety, water activity, climatic change, and environmental sanitation, may influence food safety [1]. Foodborne pathogens are a significant detrimental factor that diminishes the appeal of food for ingestion, resulting in foodborne illnesses [2]. Foodborne illnesses are linked to infections and result in significant health issues globally. The World Health Organization (WHO) estimates that these viruses cause 23 million foodborne illnesses and 5,000 fatalities annually in Europe. The rising expense of foodborne illnesses escalates medical expenditures, diminishes productivity, and contributes to death associated with sickness [3,4].

Pathogens including bacteria, viruses, fungus, yeast, and parasites are often accountable for foodborne illnesses. They infect food goods (freshly produced and uncooked items, including fish, meat, poultry, eggs, and dairy) during growth, harvesting, processing, storage, transportation, and preservation. These viruses infiltrate the human body via gastrointestinal pathways, resulting in several foodborne illnesses [5]. *Escherichia coli*, *Salmonella* species, *Clostridium* species, *Bacillus* species, *Vibrio* species, *Shigella* species, *Pseudomonas* species, *Listeria* species, *Cyclospora* species, *Campylobacter* species, *Staphylococcus* species, *Klebsiella* species, and *Acinetobacter* species. These are principal bacterial species responsible for foodborne illnesses in humans due to their pathogenic properties [6–8].

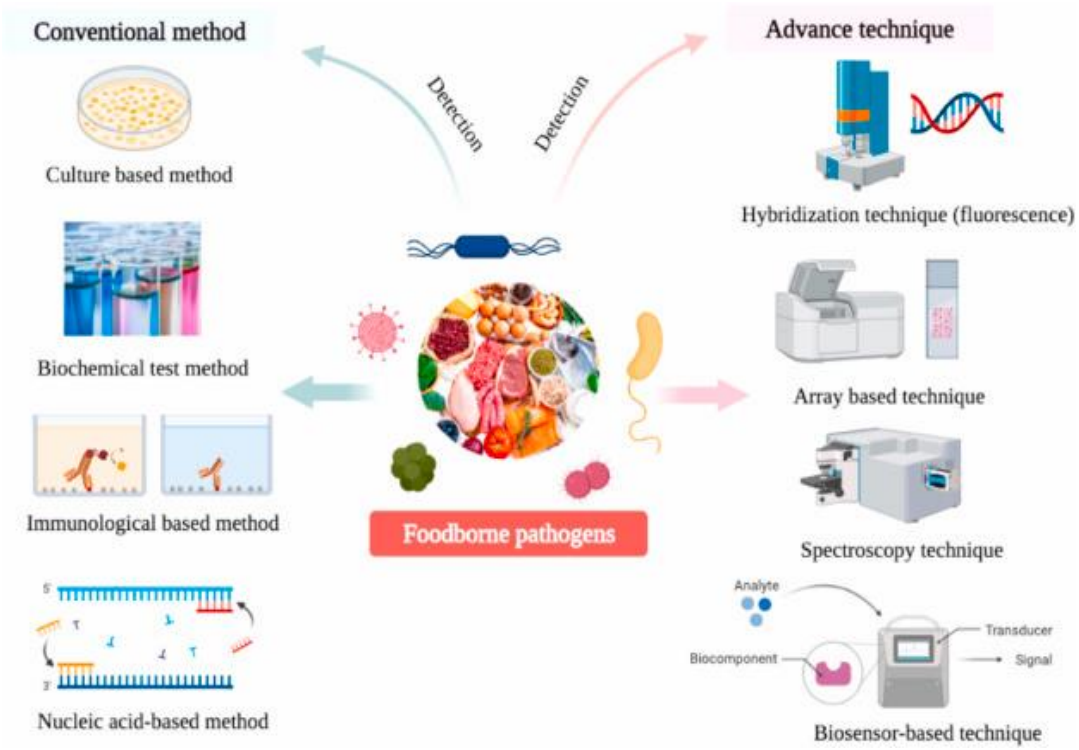
Escherichia coli is a principal pathogen implicated in foodborne illnesses, including thrombotic thrombocytopenic purpura (TTP), hemorrhagic colitis, and hemolytic uremic syndrome (HUS). The origins of E. Escherichia coli are found in unpasteurized milk, undercooked and raw meat, as well as fruits and vegetables. *Escherichia coli* O157:H7 is a strain of *E. coli*. *Escherichia coli* synthesizes the Shiga toxin implicated in human disease [9]. *Salmonella* species is present in meat, poultry, eggs, dairy products, shellfish, and other animal-derived items that may lead to foodborne illnesses such as typhoid, enterocolitis, and diarrhea [10]. *Clostridium* species have the potential to induce food-borne illnesses, particularly in newborns, pregnant women and their fetuses, elderly individuals, and those with compromised immune systems, by the ingestion of infected canned goods, fruits, and salted seafood. *Clostridium botulinum* may induce headaches, dizziness, impaired vision, weakness, paresthesia, and paralysis, and affect the human neurological system [11]. *Vibrio* species are accountable for the contamination of water and food, resulting in stomach discomfort, food poisoning, gastroenteritis, and severe dysentery, which may lead to dehydration and potentially fatal outcomes [12]. *Shigella* species may transmit illness by contaminating food items during handling and preparation, resulting in gastroenteritis and diarrhea [13]. *Campylobacter* contaminates raw dairy products, undercooked meat, and fowl, leading to human sickness.

Additionally, Listeria monocytogenes is present in raw and undercooked meats, hot dogs, unpasteurized milk, and dairy products, resulting in a foodborne illness known as listeriosis [14,15]. Additionally, additional bacteria include *Enterobacter* spp., *Staphylococcus* spp., *Campylobacter* spp., *Klebsiella* spp., *Proteus* spp., and *Citrobacter* spp. Induce foodborne illnesses [16]. In addition to these, viruses including adenovirus, norovirus, calicivirus, hepatovirus, enterovirus, and rotavirus are implicated in severe foodborne illnesses [17,18]. Adenovirus is present in contaminated food, leading to gastroenteritis in young children [19]. Calicivirus and norovirus are responsible for foodborne outbreaks, causing acute gastroenteritis and diarrhea. Hepatoviruses include the hepatitis A virus, hepatitis C virus, and hepatitis E virus, which exhibit resistance to food preservation techniques and are responsible for foodborne outbreaks [20,21]. Enterovirus induces fever, malaise, myalgia, cephalalgia, diarrhea, and emesis by the ingestion of contaminated food [22]. *Aspergillus flavus*, *Xerophilic penicillia*, *Xerophilic aspergilli*, *Eurotium halophilicum*, *Xeromyces bisporus*, *Chrysosporium*, Eurotium, and Rhizopus are present in bread, ham, dry salami, jams, salted fish, fruit cakes, dried fruit, dry grains, and confectionery, contributing to foodborne illnesses [23]. Furthermore, Ascomycetes, *Zygosaccharomyces rouxii*, *Zygosaccharomyces bailii*,

and *Debaryomyces hansenii* are the predominant yeasts encountered in food during the preparation and storage of fruits, vegetables, dairy products, cereal-based items, meat, poultry, sauces, protein-rich foods, seafood, and sugar-laden products [24]. Additionally, several parasites include fish-borne Trematodes, Ascaris, *Cryptosporidium*, *Entamoeba histolytica*, and *Echinococcus* spp. Induce food rotting [25].

Identifying foodborne pathogens is essential for maintaining food safety within the food sector. Investigation is required to detect and manage the dissemination of diseases before a significant epidemic. The detection technique is essential for regulatory compliance in food production and processing. Diverse detection techniques have been used to identify foodborne pathogens. The classification of detection techniques is categorized into many categories based on their primary benefits and drawbacks [26]. This study seeks to elucidate the traditional and innovative methodologies for detecting foodborne infections. Numerous traditional techniques exist, including culture-based methods, biochemical methods, nucleic acid-based methods (polymerase chain reaction (PCR), multiplex PCR, real-time PCR, quantitative real-time PCR (qPCR), and reverse transcriptase PCR), immunological methods (enzyme-linked immunosorbent assay (ELISA), lateral flow immunoassay, immunomagnetic separation assay, and immunofluorescence assay), as well as ultrasound techniques (Figure 1) [27–31]. Conventional procedures, although offering excellent selectivity and sensitivity, are time-consuming and labor-intensive. A variety of sophisticated techniques, including biosensor methodologies and nucleic acid sequence-based detection methods (such as DNA microarray, DNA hybridization, spectroscopic techniques, instrumental methods, aptamer-based approaches, loop-mediated isothermal amplification (LAMP), and metagenomic assays), have been developed for the detection and identification of foodborne pathogens [28,31–34].

Figure 1. The traditional and innovative methodologies for detecting foodborne infections.



2. Traditional approaches

The culture-based approach is the most ancient technology that verifies the presence of foodborne pathogens in contaminated food items. This is a systematic culture enhancement technique including selective and differential plating, confirmation, and strain typing [35]. It may be classified into two categories: pre-enrichment, which rejuvenates damaged cells, enhances the concentration of the target pathogen in food samples, and rehydrates cells from desiccated foods. Selective enrichment employs specialized media to enhance the concentration of a particular pathogen in food samples [28]. The culture

conditions are contingent upon many nutrients in the medium, incubation duration, temperature, and atmospheric composition [36].

The culture-based method is the primary approach for devising any alternative technique for the cost-effective detection of foodborne pathogens in food samples [37]. The identification of foodborne pathogens by culture-based methods is selective and specific, inhibiting the proliferation of non-essential bacteria, while a differential medium is used to isolate the targeted pathogenic organisms [38,39]. Rogosa medium is a specialized medium used to distinguish the genus *Lactobacillus* from non-lactic bacteria, using sodium acetate, acetic acid, and selective inhibitors such as nitrite, polymyxin B, and actions to suppress the development of non-lactic bacteria. The culture-based approach demonstrates a more explicit bias based on color. Purple or blue colonies on Cefsulodin-Irgasan-Novobiocin (CIN) agar indicate the presence of *Yersinia enterocolitica* [39]. The primary disadvantage of this procedure is its time-consuming nature since microbial development is sluggish; culturing may take 18–24 hours or several days and is labor-intensive. *Renibacterium salmoninarum* necessitates an incubation time of 12 weeks or more for proliferation in the selected kidney disease medium (SKDM) [40].

A biochemical test is a growth-enhancing technique that employs chemicals as indicators of pathogen presence while suppressing the proliferation of competing microorganisms. Occasionally, it entails a culture method approach, whereby the pathogen is incubated in a solid or liquid culture media [41]. Numerous biochemical assays validate the presence of certain pathogens in food samples. The tests include the oxidase test, catalase test, indole production test, methyl red test, Voges-Proskauer test, triple sugar iron agar test, blood agar plates, motility agar test, mannitol salt agar test, starch hydrolysis test, galactose hydrolysis test, carbohydrate fermentation test, citrate utilization test, urease test, hydrogen sulfide production test, nitrate reduction test, optochin sensitivity test, and bacitracin sensitivity test [31]. Lactic acid bacteria (LAB) extracted from fish and prawns may be distinguished by their production of various enzymes, acids, ammonia, indole, and gas [42].

Volatile substances, including alcohols, fatty acids, ketones, hydrocarbons, and aromatic molecules, are used for pathogen detection. Analysis of volatile compounds may be directly used for the identification of pathogens in food samples [43]. Moreover, volatile chemicals like ethanol and acetic acid may be used to identify *Saccharomyces* spp. and *Escherichia coli* with *Aspergillus* species. Inside canned tomatoes [44]. Methods such as solid phase microextraction (SPME), gas chromatography, and mass spectrometry are used for the extraction and concentration of volatile chemicals [45].

The immunological detection of foodborne pathogens involves antibody-antigen interactions, whereby a specific antigen binds to a designated antibody (either monoclonal or polyclonal). Monoclonal antibodies are preferable to polyclonal antibodies for the targeted identification of pathogens because of their specificity, sensitivity, repeatability, and dependability [46]. The sensitivity and specificity of this approach depend on the epitope location of the antibody that interacts with a particular antigen. This approach is quick and reliable in detecting infections and their toxins (e.g., mycotoxin) compared to culture-based techniques [47,48]. It identifies the pathogen's protein toxin and metabolic compounds such as proteins, glycoproteins, and polysaccharides associated with pathogen proliferation [49]. This technique is costly, requires pre-enrichment procedures, and may provide false positive findings due to cross-reactivity with different pathogen antigens, while also failing to identify injured pathogen cells [48]. A range of immunological techniques is used for pathogen identification in food. These include the immunoglobulin G (IgG) test, immunochromatographic assay, immunofluorescence assay, immunomagnetic separation, latex agglutination, immunodiffusion assays, lateral flow immunoassay, immunoglobulin-linked immunosorbent assay (ELISA), and gold-labeled immunosorbent assay (GLISA).

3. Biosensor

A biosensor is an analytical instrument designed to identify an analyte (target pathogen) by biological sensing components, generating a distinct, quantifiable signal, while a physical transducer captures, amplifies, processes, and analyzes the signal [50,51]. The biosensor bead detection approach is simple,

economical, quick, and highly specific for the identification of foodborne pathogens. Conversely, traditional approaches have reduced detection capabilities, prolonged duration, high labor intensity, less selectivity, and decreased specificity. This detection approach is superior for detecting foodborne pathogens compared to traditional methods since the latter cannot detect VBNC (Viable but nonculturable) organisms in food [52]. Biological sensing components that identify target foodborne pathogens are referred to as receptors, which include antibodies, enzymes, aptamers, antimicrobial peptides, bacteriophages, biomimetics, cells, tissues, and nucleic acid probes. They are fixed on the transducer's surface to engage with certain analyte molecules [53]. A biosensor is constructed on a supporting matrix on which receptors are affixed for the detection of analytes. The predominant sensor matrices are paper, carbon paste, graphite, glassy carbon electrode (GCE), indium tin oxide (ITO), and screen-printed electrodes (SPE), chosen according to the analyte and transducer mechanism. The efficacy of a biosensor is contingent upon the characteristics of the material, its design, and the method of sensor matrix production [50]. A transducer is the component of a biosensor that transforms signals from the recognition element into a quantifiable format. The signal may be quantified by direct or indirect methods. Direct detection involves identifying a target using a single ligand (e.g., antibody), while indirect detection entails identifying a target using a dual ligand system, where the main ligand binds to the sensor's surface to collect the analyte, and the secondary ligand produces a signal [54]. Biosensors are categorized into three primary types—electrochemical, optical, and piezoelectric—according to the nature of their signal transducers.

4. Molecular diagnostics using CRISPR-Cas technology for the identification of foodborne pathogens

The clustered regularly interspaced short palindromic repeats-associated nuclease (CRISPR-Cas protein) has the potential to address the aforementioned limitations in nucleic acid detection, owing to its numerous advantages, including the capacity to differentiate single nucleotide polymorphisms (SNPs), identify targets at physiological temperatures, and execute rapid detection with remarkable sensitivity and specificity [55]. Consequently, CRISPR-Cas-based diagnostics have been used in food safety, environmental pollution, life sciences, and several other fields [56]. Furthermore, novel diagnostic methodologies have been implemented by integrating Cas proteins with various technologies, including protein aptamers, isothermal amplification, lateral flow, biosensors, biomagnetic beads, and biochips, which are increasingly favored for the identification of foodborne pathogens such as *Escherichia coli*, *Salmonella* spp., *Staphylococcus aureus*, *Vibrio parahaemolyticus*, and *Listeria monocytogenes* [57].

The Cas enzyme, derived from bacteria and archaea, functions to break the nucleic acids of invading viruses as a defensive mechanism and serves as the primary component of CRISPR-Cas-based systems. Recently, the CRISPR-Cas system has been used for nucleic acid detection, eliciting considerable attention [58]. It has been used to alter RNA and genomes. The CRISPR-Cas systems are categorized into two classes: class 1 and class 2. The class 2 system comprises Cas9, Cas12, Cas13, and Cas14, which constitute the most prevalent toolkit for nucleic acid identification [59]. In the majority of investigations, the CRISPR protein used is Cas9, which may be combined with other techniques to provide adaptable ways for pathogen identification. Nonetheless, precise labeling of samples is essential to indicate the detection readout [57]. Cas12 may directly target dsDNA without further processing of the amplified sequence; however, a PAM (Protospacer-adjacent motif) is required for nucleic acid-targeting [60]. Cas13 is SHERLOCK (particular High-Sensitivity Enzymatic Reporter Unlocking) using RPA (Recombinase Polymerase Amplification) technology to detect particular nucleic acids rapidly (within 5 minutes). Nonetheless, the principal drawbacks of this method are that sample amplification in detection complicates quantitative analysis, and optimizing all reactions in the detection process requires specialized biology knowledge [61]. Cas14 proteins efficiently cleave targeted single-stranded DNA (ssDNA) without requiring a PAM for activation. Cas14 exhibited reduced tolerance for nucleotide base mismatches between the target and crRNA compared to Cas12, making it an efficient instrument for the accurate identification of SNPs [62].

5. Conclusions

This study examines traditional and sophisticated detection techniques for foodborne pathogens. Timely identification of microorganisms in food is crucial for guaranteeing food safety and preventing

detrimental foodborne illnesses. Traditional procedures are only conducted in laboratories. The drawbacks of the traditional technique include time consumption, substantial resource demands, contamination risks, and the need for a professional team to achieve optimal outcomes. The benefits of sophisticated approaches include expedited reaction, simplicity, robust intensity, cost-effectiveness, and swift data analysis. Both traditional and sophisticated approaches include distinct benefits and drawbacks; hence, when selecting a method, the chosen approach must be accurate, trustworthy, cost-effective, selective for a specific foodborne pathogen, and sufficiently rapid to provide consistent findings. Additionally, problems persist in the industrial-scale implementation, including the need for expedited and dependable sample preparation methods and advanced detection techniques for foodborne pathogens. The development of novel methods for detecting hazardous infections is contingent upon the kind of food and its nutritional constituents (protein, fat, fiber, and carbs). Consequently, distinct sample preparation techniques and analytical instruments are required to detect pathogens in each food item. Subsequent research should address these analytical limitations to provide an effective method for the complete detection of foodborne pathogens. Furthermore, qualities like precision, accuracy, validation, environmental sustainability, cost-effectiveness, and commercial scalability must be evaluated to develop a distinctive and dependable detection system.

References

1. B. Ramakrishnan, et al., Organic farming: does it contribute to contaminant-free produce and ensure food safety? Sci. Total Environ. 769 (2021) 145079.
2. Y.M. Somorin, O.A. Odeyemi, C.N. Ateba, Salmonella is the most common foodborne pathogen in African food exports to the European Union: analysis of the rapid alert system for food and feed (1999–2019), Food Control 123 (2021), 107849.
3. K. Flynn, et al., An introduction to current food safety needs, Trends Food Sci. Technol. 84 (2019) 1–3.
4. S. Hoffmann, L. Ashton, J.W. Ahn, Food safety: a policy history and introduction to avenues for economic research, Appl. Econ. Perspect. Pol. 43 (2) (2021) 680–700.
5. D. Pissuwan, et al., Single and multiple detections of foodborne pathogens by gold nanoparticle assays, Wiley Interdiscipl. Rev.: Nanomed. Nanobiotechnol. 12 (1) (2020), e1584.
6. R.E. Timme, M. Sanchez Leon, M.W. Allard, Utilizing the public GenomeTrakr database for foodborne pathogen traceback, in: Foodborne Bacterial Pathogens, Springer, 2019, pp. 201–212.
7. A.C. Foddai, I.R. Grant, Methods for detection of viable foodborne pathogens: current state-of-art and future prospects, Appl. Microbiol. Biotechnol. 104 (10) (2020) 4281–4288.
8. J. Tao, et al., A multiplex PCR assay with a common primer for the detection of eleven foodborne pathogens, J. Food Sci. 85 (3) (2020) 744–754.
9. M.M.A. Zeinhom, et al., A portable smart-phone device for rapid and sensitive detection of E. coli O157: H7 in Yoghurt and Egg, Biosens. Bioelectron. 99 (2018) 479–485.
10. L. Lin, et al., Immuno-and nucleic acid-based current technique for Salmonella detection in food, Eur. Food Res. Technol. 246 (3) (2020) 373–395.
11. D.A. Leffler, J.T. Lamont, Clostridium difficile infection, N. Engl. J. Med. 372 (16) (2015) 1539–1548.
12. C. Baker-Austin, et al., Vibrio spp. infections, Nat. Rev. Dis. Prim. 4 (1) (2018) 1–19.
13. N. Elahi, et al., A fluorescence Nano-biosensors immobilization on Iron (MNPs) and gold (AuNPs) nanoparticles for detection of Shigella spp, Mater. Sci. Eng. C 105 (2019) 110113.
14. P. Vizzini, et al., Highly sensitive detection of Campylobacter spp. in chicken meat using a silica nanoparticle enhanced dot blot DNA biosensor, Biosens. Bioelectron. 171 (2021) 112689.
15. N.F. Silva, et al., Emerging electrochemical biosensing approaches for detection of Listeria monocytogenes in food samples: an overview, Trends Food Sci. Technol. 99 (2020) 621–633.
16. C. Franz, et al., Reprint of: microbial food safety in the 21st century: emerging challenges and foodborne pathogenic bacteria, Trends Food Sci. Technol. 84 (2019) 34–37.
17. D. Rodriguez-Lazaro, et al., Virus hazards from food, water and other contaminated environments, FEMS Microbiol. Rev. 36 (4) (2012) 786–814.
18. G. Purpari, et al., Molecular characterization of human enteric viruses in food, water samples, and surface swabs in Sicily, Int. J. Infect. Dis. 80 (2019) 66–72.

19. L. Maunula, et al., The presence of norovirus and adenovirus on environmental surfaces in relation to the hygienic level in food service operations associated with a suspected gastroenteritis outbreak, Food Environ. Virol. 9 (3) (2017) 334–341.
20. J.R. Rispens, et al., Notes from the field: multiple cruise ship outbreaks of norovirus associated with frozen fruits and berries—United States, 2019, MMWR (Morb. Mortal. Wkly. Rep.) 69 (16) (2020) 501.
21. J.-m. Yu, et al., A novel hepatovirus identified in wild woodchuck Marmota himalayana, Sci. Rep. 6 (1) (2016) 1–11.
22. L. Meyers, et al., Enterovirus D68 outbreak detection through a syndromic disease epidemiology network, J. Clin. Virol. 124 (2020) 104262.
23. J.I. Pitt, A.D. Hocking, The ecology of fungal food spoilage, in: Fungi and Food Spoilage, Springer, 2009, pp. 3–9.
24. L.N. Shwaiki, et al., Inhibitory effect of four novel synthetic peptides on food spoilage yeasts, Int. J. Food Microbiol. 300 (2019) 43–52.
25. R. Singh, B. Anderson, The major types of food spoilage: an overview, in: Understanding and Measuring the Shelf-Life of Food, 2004, pp. 3–23.
26. A. Lamas, et al., Transcriptomics: a powerful tool to evaluate the behavior of foodborne pathogens in the food production chain, Food Res. Int. 125 (2019) 108543.
27. K. Willems, et al., Detection and identification of fish pathogens: what is the future? Isr. J. Aquac. Bamidgeh 60 (2008) 20501.
28. H.P. Dwivedi, L.-A. Jaykus, Detection of pathogens in foods: the current state-of-the-art and future directions, Crit. Rev. Microbiol. 37 (1) (2011) 40–63.
29. B. Priyanka, R.K. Patil, S. Dwarakanath, A review on detection methods used for foodborne pathogens, Indian J. Med. Res. 144 (3) (2016) 327.
30. J. Li, et al., Rapid detection methods for bacterial pathogens in ambient waters at the point of sample collection: a brief review, Clin. Infect. Dis. 71 (Supplement_2) (2020) S84–S90.
31. A. Saravanan, et al., Methods of detection of food-borne pathogens: a review, Environ. Chem. Lett. 19 (1) (2021) 189–207.
32. V. Velusamy, et al., An overview of foodborne pathogen detection: in the perspective of biosensors, Biotechnol. Adv. 28 (2) (2010) 232–254.
33. J. Amani, S.A. Mirhosseini, A.A.I. Fooladi, A review approaches to identify enteric bacterial pathogens, Jundishapur J. Microbiol. 8 (2) (2015).
34. H. Kumar, et al., Detection of bacterial pathogens and antibiotic residues in chicken meat: a review, Foods 9 (10) (2020) 1504.
35. S.O. Kim, S.S. Kim, Bacterial pathogen detection by conventional culture-based and recent alternative (polymerase chain reaction, isothermal amplification, enzyme linked immunosorbent assay, bacteriophage amplification, and gold nanoparticle aggregation) methods in food samples: a review, J. Food Saf. 41 (1) (2021), e12870.
36. J.-C. Lagier, et al., Current and past strategies for bacterial culture in clinical microbiology, Clin. Microbiol. Rev. 28 (1) (2015) 208–236.
37. R.L. Bell, et al., Recent and emerging innovations in Salmonella detection: a food and environmental perspective, Microb. Biotechnol. 9 (3) (2016) 279–292.
38. U. Schillinger, W. Holzapfel, Culture media for lactic acid bacteria, in: Progress in Industrial Microbiology, Elsevier, 2003, pp. 127–140.
39. S.D. Weagant, A new chromogenic agar medium for detection of potentially virulent Yersinia enterocolitica, J. Microbiol. Methods 72 (2) (2008) 185–190.
40. E. Benediktsdo´ttir, S. Helgason, S. Gudmundsdo´ttir, Incubation time for the cultivation of Renibacterium salmoninarum from Atlantic salmon, Salmo salar L., broodfish, J. Fish. Dis. 14 (1) (1991) 97–102.
41. D. Singh, A. Sharma, G.K. Saini, Biochemical and molecular characterisation of the bacterial endophytes from native sugarcane varieties of Himalayan region, 3 Biotech 3 (3) (2013) 205–212.
42. P.S. Nair, P.K. Surendran, Biochemical Characterization of Lactic Acid Bacteria Isolated from Fish and Prawn, 2005.

43. E. Tait, et al., Use of volatile compounds as a diagnostic tool for the detection of pathogenic bacteria, TrAc. Trends Anal. Chem. 53 (2014) 117–125.
44. F. Bianchi, et al., Differentiation of the volatile profile of microbiologically contaminated canned tomatoes by dynamic headspace extraction followed by gas chromatography–mass spectrometry analysis, Talanta 77 (3) (2009) 962–970.
45. W. Filipiak, et al., Molecular analysis of volatile metabolites released specifically by Staphylococcus aureus and Pseudomonas aeruginosa, BMC Microbiol. 12 (1) (2012) 1–16.
46. X. Zhao, et al., Advances in rapid detection methods for foodborne pathogens, J. Microbiol. Biotechnol. 24 (3) (2014) 297–312.
47. I.-H. Cho, A. Bhunia, J. Irudayaraj, Rapid pathogen detection by lateral-flow immunochromatographic assay with gold nanoparticle-assisted enzyme signal amplification, Int. J. Food Microbiol. 206 (2015) 60–66.
48. Y. Wang, J.K. Salazar, Culture-independent rapid detection methods for bacterial pathogens and toXins in food matrices, Compr. Rev. Food Sci. Food Saf. 15 (1) (2016) 183–205.
49. W.B. Valderrama, et al., Commercially available rapid methods for detection of selected food-borne pathogens, Crit. Rev. Food Sci. Nutr. 56 (9) (2016) 1519–1531.
50. B. Purohit, et al., Biosensor nanoengineering: design, operation, and implementation for biomolecular analysis, Sens. Int. 1 (2020) 100040.
51. R. Zhang, et al., Nanomaterial-based biosensors for sensing key foodborne pathogens: advances from recent decades, Compr. Rev. Food Sci. Food Saf. 19 (4) (2020) 1465–1487.
52. A. Kumar, et al., Aptamer technology for the detection of foodborne pathogens and toXins, in: Advanced Biosensors for Health Care Applications, Elsevier, 2019, pp. 45–69.
53. Y. Shen, L. Xu, Y. Li, Biosensors for rapid detection of Salmonella in food: a review, Compr. Rev. Food Sci. Food Saf. 20 (1) (2021) 149–197.
54. Y.D. Han, H.J. Chun, H.C. Yoon, Low-cost point-of-care biosensors using common electronic components as transducers, BioChip Journal 14 (1) (2020) 32–47.
55. L. Li, et al., CRISPR-Cas-mediated diagnostics, Trends Biotechnol. 40 (11) (2022) 1326–1345.
56. Y. Lu, et al., CRISPR-Cas based molecular diagnostics for foodborne pathogens, Crit. Rev. Food Sci. Nutr. (2022) 1–21.
57. X. Wang, X. Shang, X. Huang, Next-generation pathogen diagnosis with CRISPR/Cas-based detection methods, Emerg. Microb. Infect. 9 (1) (2020) 1682–1691.
58. D. Mota, et al., CRISPR/Cas Class 2 systems and their applications in biotechnological processes, Genet. Mol. Res. 20 (2020) 1–10.
59. J.P. Broughton, et al., CRISPR–Cas12-based detection of SARS-CoV-2, Nat. Biotechnol. 38 (7) (2020) 870–874.
60. M.J. Kellner, et al., SHERLOCK: nucleic acid detection with CRISPR nucleases, Nat. Protoc. 14 (10) (2019) 2986–3012.
61. L.B. Harrington, et al., Programmed DNA destruction by miniature CRISPR-Cas14 enzymes, Science 362 (6416) (2018) 839–842.
62. C. Song, et al., Dual FITC lateral flow immunoassay for sensitive detection of Escherichia coli O157: H7 in food samples, Biosens. Bioelectron. 85 (2016) 734–739.

التقدم في علم الأوبئة للأمراض المنقولة عبر الغذاء: مراجعة شاملة لطرق الكشف، ديناميات المpathogens ، وآثار الصحة العامة

الملخص

الخلفية :تظل الأمراض المنقولة عبر الغذاء قضية رئيسية في الصحة العامة، حيث تسبب الم pathogens ملايين الإصابات وآلاف الوفيات سنويًا. تقدر منظمة الصحة العالمية أن الأمراض المنقولة عبر الغذاء تؤدي إلى حوالي 23 مليون حالة مرضية و5,000 حالة وفاة كل عام في أوروبا وحدها. تستعرض هذه المراجعة التقدمات الأخيرة في علم الأوبئة لل pathogens المنقولة عبر الغذاء، مع تسليط الضوء على تأثير عوامل مثل ممارسات سلامة الغذاء، والصرف الصحي البيئي، وتغير المناخ على انتقال الأمراض.

الطرق :قمنا بإجراء تحليل شامل لكل من طرق الكشف التقليدية والمبتكرة لل pathogens المنقولة عبر الغذاء، بما في ذلك التقنيات المعتمدة على الثقافة، والاختبارات الكيميائية الحيوية، والطرق المناعية، وتقنيات المستشعرات الحيوية المتقدمة. من خلال مراجعة منهجية للأدبيات من مصادر محكمة، حددنا الاتجاهات الهامة في انتشار pathogens وفعالية الكشف عنها.

النتائج :تشير النتائج إلى أن الطرق التقليدية، على الرغم من موثوقيتها، غالبًا ما تكون مستهلكة للوقت وتتطلب جهدًا كبيرًا، حيث قد تستغرق تقنيات الثقافة عدة أيام للتأكيد. بالمقابل، تقدم تقنيات المستشعرات الحيوية الحديثة والتشخيصات الجزيئية، بما في ذلك أنظمةCRISPR-Cas ، كشفًا سريعًا مع حساسية وخصوصية مرتفعة، مما يسمح بالتدخل الفوري في إدارة سلامة الغذاء.

الاستنتاج :على الرغم من التقدم الكبير المحرز في الكشف وفهم pathogens المنقولة عبر الغذاء، لا تزال هناك تحديات في تنفيذ هذه الطرق المتقدمة في البيئات الصناعية. ينبغي أن تركز الأبحاث المستقبلية على تحسين تقنيات الكشف لضمان التعرف السريع والدقيق علىpathogens ، مما يعزز سلامة الغذاء ونتائج الصحة العامة.

الكلمات المفتاحية :الأمراض المنقولة عبر الغذاء، كشفpathogens ، علم الأوبئة، المستشعرات الحيوية، الصحة العامة