Application of Modern Biotechnology in Food Pathogenic Microorganisms and Safety Detection

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Abstract: With the continuous progress and development of modern economic society, people pay more attention to food safety issues, which are related to the health and life safety of the people. Nevertheless, the domain of food safety continues to confront numerous challenges and complexities, indicating that the prevailing conditions are intricate.Therefore, it is crucial to flexibly use modern biological detection technology for food safety testing. This study focuses on describing and analyzing the application of five modern biotechnologies in the detection of foodborne pathogens and safety, discussing the development prospects of modern biotechnology in food testing, in order to achieve precise detection of pathogenic microorganisms carried in food and ensure consumer health and safety.

Keywords: Foodborne Pathogens; Food Safety; Modern Biological Detection Technology; Application Value

1. Introduction

Food, as one of the most basic material components in people's daily lives, is closely related to the survival and development of human beings. The future trend of food industry development lies in the deep integration of food engineering, biological science, and information technology. Faced with the continuous increase in population, severe challenges posed by climate change, as well as multiple complex factors such as resource scarcity, environmental degradation, and public health issues intertwined impact, ensuring the sustainability, nutrition and safety of future food supply has become a daunting task.

The issue of food quality and safety has attracted widespread attention. Concurrent with the swift progression of societal economic and technological advancements, people's living standards are steadily improving, leading to an increased demand for food health and safety at new heights. Food safety testing is significant; it directly relates to public health, economic development and social stability. It is an important means to ensure the safety of the food supply chain while maintaining public health and promoting the development of the food industry.

This study will focus on describing and analyzing five modern biotechnologies' applications in pathogenic microorganism detection and safety testing in foods; exploring prospects for modern biotechnology in food testing to achieve precise detection of pathogenic microorganisms carried in foods for safeguarding consumer health and safety purposes.

2. Food Safety Issues and The Shortcomings of Traditional Detection

Techniques are closely related to nutrition regulation and food security. Unsafe food can lead to a vicious cycle of disease and malnutrition, impacting human health. Common food safety problems include inappropriate employment of food additives, the presence of microbial and heavy metal pollutants, and the surplus of pesticide and veterinary drug residues represent significant issues in the food industry, as well as counterfeit products. Infectious or toxic foodborne diseases caused by different bacteria, viruses, parasites, fungi and mycotoxins pose a significant threat to human health.

Traditional food testing methods involve routine physical-chemical tests and instrumental analysis for determining chemical composition, microbial contamination, residue levels, and toxin content in foods. However, studies have shown that traditional food safety testing techniques suffer from low efficiency, high costs, and long processing times. To

effectively address these issues and overcome the deficiencies of traditional food testing techniques in a timely manner, researchers both domestically and internationally continue to innovate using modern biotechnology to promote advancements in food safety inspection work [1].

3. Overview of Biotechnology

Biotechnology encompasses the utilization of biological systems and living organisms for the development and production of a diverse array of products. It involves in-depth research, modification, and utilization of organisms, biological tissues, cells, genes, etc., to achieve specific application purposes. Biotechnology mainly conducts foodborne pathogen detection through forms such as gene editing and immunological testing. As modern biotechnology progresses and is integrated into food science, the precision of food safety assessments has been notably enhanced. This advancement furnishes robust technical backing for the oversight of food safety, thereby protecting the well-being and legal entitlements of consumers.

Modern biotechnology plays a crucial role in food safety: 1) detecting microbial components in food to assess its hygiene status and safety; 2) detecting pesticide residues in food to ensure its safety and compliance; 3) analyzing nutritional components in food such as proteins, fats, etc., to evaluate its nutritional value [2].

4. The Importance of Modern Biotechnology in Food Testing

Historically, traditional physical and chemical testing approaches, as well as those reliant on instrumentation, exhibited inherent limitations, making it difficult to meet the rapid development requirements of the new era. In order to adapt to the changes of the times, food safety testing has continuously combined with new technologies and new models, developing in a completely new direction. The use of modern biotechnology in food testing has attracted more attention and attention from people, as it can play a significant role and value.

Modern biotechnology has brought an innovative, efficient, and highly accurate detection method to the field of food testing. It not only reduces detection costs but also efficiently detects pathogenic microorganisms carried in food while accurately detecting pesticide residues in food to ensure consumer health. During the process of food testing, modern biotechnology can effectively control the spread of microorganisms and conduct in-depth analysis on the composition and quality of food, providing scientific basis for healthy dietary choices at a data level [3].

5. Application of Modern Biotechnology in Food Detection

5.1 Polymerase Chain Reaction

Polymerase chain reaction (PCR) , is a method for efficient amplification of specific DNA sequences outside the organism, and it plays an important role in the field of food safety testing. In the field of food pathogen microorganism detection, polymerase chain reaction (PCR) has demonstrated its ability to rapidly identify and quantitatively detect pathogenic microorganisms in food, such as Salmonella and E. coli, thereby helping to effectively prevent large-scale outbreaks of foodborne diseases. Latest gel-based cassette polymerase chain reactions technology has been applied in testing pathogenic Escherichia coil in meat samples by its accurate temperature regulation, faster light delivery and sensitive fluorescent recording [4-5].

With the assistance of DNA polymerase and by designing specific primers, PCR technology can specifically amplify target microbial DNA, thus achieving precise detection of pathogenic microorganisms in food samples. However, PCR technology also has certain limitations in its application process; for example, it may produce false positive results when detecting dead bacteria, leading to testing errors. In addition, PCR experiments require high technical requirements for laboratory environment and operating personnel; strict control over reaction conditions is needed to avoid contamination and errors [6].

5.2 Nucleic Acid Hybridization

Nucleic acid hybridization, is an advanced technology developed in the 1970s based on the principles of genetic engineering, and has become an important part of modern biotechnology. Based on the complementary pairing of DNA bases, Nucleic acid hybridization technology can rapidly detect

nucleic acids at levels as low as 10-9 to 10-12 with high sensitivity, specifically recognizing labeled DNA probes with target DNA sequences, ultimately achieving rapid detection of pathogenic microorganisms in food.

In food testing, Nucleic acid hybridization technology is mainly used to detect pathogenic microorganisms such as E. coli, Staphylococcus aureus, Aspergillus flavus and other common pathogens and toxin-producing bacteria [7-8]. In recent survey, researchers have introduced an innovative peptide nucleic acid fluorescence in situ hybridization (PNA-FISH) technique, specifically designed for the precise identification of Salmonella strains. This novel approach facilitates a more expeditious analytical process when juxtaposed with conventional detection methods [9].

5.3 Biological Chip Technology

Biological chip technology is an advanced microanalysis technique, which immobilizes a large number of biological macromolecules in a neat and orderly flat molecular array on the surface of carriers such as silicon wafers and glass slides. This technology uses the photo-induced in situ synthesis method to hybridize the immobilized biological molecules on the surface with labeled target molecules of the food samples to be tested, and combines professional equipment to efficiently and quantitatively detect and analyze the hybridization signal intensity, thereby determining the actual quantity of target molecules in the sample. By comparing it with standard samples, it ultimately confirms whether food is contaminated by pathogenic microorganisms. Suspended Array Technology (SAT), as the first biological chip technology approved by the US Food and Drug Administration, has demonstrated rapid, accurate, sensitive advantages in detecting foodborne pathogens, pesticide residues, genetically modified foods, and allergens [10].

5.4 Biological Sensor Inspection Technology

Biological sensor is a highly sensitive instrument that converts biological concentration into electrical signals. This technology combines biological recognition elements with signal transducers to convert biological information parameters into electrical signals for rapid and accurate detection of specific components in food samples. In food safety testing, biosensor technology finds its principal application in four distinct domains: 1) detecting the freshness of food; 2) detecting effective components in food; 3) detecting additive components in food; 4) detecting pathogenic microorganisms in food. Biological sensors can achieve both signal reception and conversion functions, with high accuracy and good repeatability, enabling precise analysis of pathogenic microorganism content in food and providing timely data support for food safety monitoring. Metal-organic frameworks (MOFs), as a type of crystalline porous material, can be used to construct high-performance biological sensors when combined with appropriate functionalization, widely used in medical diagnostics, food safety testing, and other fields [11].

5.5 Biological Immunoassay Technology

Biological immunoassay technology is based on the specific binding principle between antigens and antibodies, and it achieves rapid and accurate detection of trace components in food by effectively combining with modern detection techniques. Biological immunoassay technology mainly includes enzyme-linked immunosorbent assay (ELISA), immunofluorescence technology, radioimmunoassay (RIA), and immunogold colloidal technology. ELISA has been widely used in raw milk testing due to its simple operation, low cost, and intuitive result judgment. RIA uses radioactive isotopes as markers to label and track antigens or antibodies in food, making it suitable for detecting hormones and small molecule drugs. Immunoassays are considered one of the best candidate methods for toxin detection. In mold toxin analysis, biological immunoassay technology can simultaneously detect multiple mold toxins while improving the quality of results [12-13].

6. The Development Prospects of Modern Biotechnology in Food Testing

As the social economy evolves and the quality of life for individuals elevates, food safety issues have received increasing attention. Modern biotechnology has the advantages of low consumption, high efficiency, safety, and

precision. More importantly, it is flexible in practical applications, which means that it can complementarily detect pathogenic microorganisms in food through multiple technologies, showing great potential and application value in the field of food safety testing.

Modern biotechnologies such as immunological techniques, biosensors, and biochip technologies can rapidly and accurately detect additives, heavy metal contamination, pesticide residues, and pathogenic microorganisms in food. Although the detection process of modern biotechnology requires high technical content and complex practical operation with susceptibility to external environmental interference limitations compared to traditional food safety testing techniques; it not only reduces detection costs but also efficiently detects pathogenic microorganisms carried by food more precisely detects pesticide residues to ensure consumer health.

The future development of food safety testing technology will be multidimensional focusing on innovation and application expansion of biotechnology by developing highly sensitive rapid detection methods combined with automated intelligent information technology for comprehensive monitoring harmful components in foods. Integrating various detection methods such as biosensors gene detection immunological techniques from technological research & innovation improving equipment performance & accuracy perfecting standardized & normalized testing methods strengthening training & assessment for test personnel etc., ensuring the accuracy reliability while reducing costs making food safety testing more widespread convenient contributing significantly to global food security public health protection.

7. Conclusion

With the continuous improvement of modern scientific and technological level, new food microbiological detection technologies have begun to play a role, which can accurately and quickly detect pathogenic microorganisms in food. At present, microbial contamination is the fundamental cause of food safety issues, and the emergence of food biological detection technology provides good support for solving such problems. Modern biotechnology will continue to be an important tool to ensure food safety, providing consumers with safer and healthier dietary choices through continuous technological innovation and application expansion.

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