

Assessment Of Risk Factors in The Production, Processing, Storage and Transportation of Pre-Prepared Meals

Jinglin Deng *

College of Life Sciences, South China Agricultural University, Guangzhou, China

* Corresponding Author Email: 202015140502@stu.scau.edu.cn

Abstract. Microbial contamination and chemical contamination are the main factors that cause food safety and quality problems in pre-prepared meals. According to the order of raw material production, processing, storage and transportation in the pre-prepared meal supply chain, this article analyzes the potential microbial risk points from the perspective of contamination pathways, lists common food contamination microorganisms and their hazards, and divides common chemical contamination according to production links, aiming to warn the executors of the corresponding processes to prevent and control potential microbial contamination and chemical hazards, so as to control the food safety risks of the pre-prepared meal industry at a macro level. Through analysis, this article found that if these measures are effectively implemented, the food safety contamination of prepared vegetable products will be significantly reduced, and product quality and market competitiveness will also be improved. Future research can focus more on building a comprehensive food safety prevention and control system in the prepared food industry to achieve healthy and sustainable development.

Keywords: Pre-prepared food, food safety, microbiological hazards, chemical hazards.

1. Introduction

In recent years, with the acceleration of China's industrialization process, food processing technology is constantly improving, and the research and development of pre-prepared meals has also developed rapidly. More and more different types of food raw materials can be made into pre-prepared meal products through the latest technical means. Whether it is vegetables and fruits, poultry, livestock, eggs, milk, or seafood products, almost all of them have corresponding pre-prepared meal products. In addition, with the development of China's cold chain logistics, e-commerce, and Internet economy, the supply chain of pre-prepared meals has gradually improved. These pre-prepared meal products have been placed on the tables of countless people and have penetrated into all aspects of people's daily diet.

Relevant survey data show that the scale of China's pre-prepared meal market will exceed 500 billion yuan in 2023, and may exceed 1 trillion yuan in 2026 [1]. Such a large market scale and astonishing market expansion speed also reflect that China currently has a huge market demand for pre-prepared meals. On the one hand, for merchants in the catering industry, the cost of pre-prepared dishes is lower than that of fresh ingredients, the dishes are served quickly, the quality control is consistent, and the storage time is long, which makes more and more merchants choose to use pre-prepared dishes. On the other hand, for retail consumers, the convenience and easy accessibility of pre-prepared dishes also reduce the learning cost and time cost of consumer in cooking. However, at this stage, In China, pre-prepared food industry as a whole has just started, and the relevant national standards and regulatory systems need to be improved. There are still many problems in the production, processing, storage, transportation and consumption processes. However, the non-disclosure and non-transparency of the production and processing stages have made people still have great concerns about the food safety of pre-prepared dishes.

Therefore, this article will focus on the food safety risks existing in the production and processing stages, storage and transportation stages of food, aiming to provide improvement ideas for solving the food hygiene and safety problems existing in the development of the pre-prepared food industry

today, and provide reference for the innovation, upgrading and sustainable development of the pre-prepared food industry in the future.

2. Microbial Hazards Faced by Pre-prepared Meals

Pre-prepared food is a very broad food category. According to the type of raw materials, pre-prepared food can be simply divided into pre-prepared fruit and vegetable products, pre-prepared aquatic products, pre-prepared poultry and livestock products, etc. Its supply chain includes four links, namely production, processing, storage and transportation, and consumption.

2.1. Sources and Transmission Routes of Food Microbial Contamination

2.1.1 Production of Raw Materials for Pre-prepared Meals

From the perspective of the raw material acceptance stage of pre-prepared dishes, different types of raw materials are susceptible to slightly different sources of microbial contamination. Poultry and livestock raw materials are mainly purchased from farms and slaughterhouses. Improper breeding methods or insufficient disinfection of the processing environment will put pre-prepared dishes at risk of microbial contamination. This type of contamination mainly comes from a variety of pathogenic bacteria, such as *Escherichia coli*, *Salmonella enteritidis*, and *Staphylococcus aureus*. For aquatic pre-prepared dishes, the aquaculture and fishing processes of their raw materials are often accompanied by contamination by pathogenic bacteria and putrefactive bacteria. These microorganisms and their toxins can cause food poisoning [2]. Similarly, grain-based pre-prepared dishes are also susceptible to mold and bacteria when stored under poor conditions, leading to food spoilage [3]. In addition, the raw materials of fruit and vegetable pre-prepared dishes are also threatened by microbial contamination, especially the soil environment and the quality of irrigation water, which directly affect the safety of fruits and vegetables. Studies have shown that microorganisms such as coliform bacteria and *Bacillus cereus* can often be detected in lettuce and the water and soil environment of vegetable bases [4]. In particular, organic fertilizers such as feces may become a potential source of contamination for *Escherichia coli* (such as O157:H7) in fruits and vegetables. This strain is widely present in soil and water and can be transmitted to the surface of fruits and vegetables through contaminated irrigation water, where it can survive for a long time and remain pathogenic.

2.1.2 Pre-prepared Food Processing

There are many sources of microbial contamination during the processing of raw materials for pre-prepared dishes, but the main causes of microbial contamination are improper cleaning of production equipment and tools and poor sanitary environment. A detailed analysis of the contamination pathways can be summarized into three categories: direct contact contamination, cross contamination, and bioaerosol-mediated contamination. Direct contact contamination refers to microorganisms directly attached to the surface of food or penetrating into its interior, which is often caused by improper contact with the raw materials themselves or during processing. Cross contamination focuses on the transfer of contaminants, which is common when sharing processing tools or equipment. If they are not thoroughly cleaned and disinfected, microorganisms on one food may migrate to another food. In addition, bioaerosols, as a transmission medium, should not be ignored. It refers to tiny particles containing microorganisms suspended in the air that can be brought to the surface or interior of food through air flow. In the food processing environment, the daily activities of operators, such as coughing, sneezing, or talking, may inadvertently release these microbial aerosols, thereby contaminating the food.

As a barrier between food and the external environment, the packaging of pre-prepared meals itself may also become a potential source of microbial contamination. This risk mainly stems from improper selection of packaging materials, contamination during the manufacturing process, and cross-contamination during use. First of all, material selection is crucial to the safety of food

packaging. If the packaging material fails to meet the established hygiene standards or is not suitable for the storage needs of specific foods, it may cause packaging contamination. For example, if some plastic packaging contains bad additives or is prone to release harmful substances under high temperature conditions, it will directly threaten food safety. Secondly, lax control during the manufacturing process is also an important source of contamination. On the production line of packaging materials, if the external pollution source is not effectively isolated, or the cleaning and disinfection measures are not in place, it may cause the attachment of microorganisms or other contaminants, and then cross-contamination will occur.

2.1.3 Storage and Transportation of Pre-prepared Meals

Contamination during the storage and transportation of pre-prepared meals mainly comes from inappropriate storage conditions, cross-contamination and various factors in the transportation process. Specifically, improper storage conditions, such as failure to effectively control temperature, humidity and ventilation conditions, will promote the growth and reproduction of microorganisms, thereby contaminating food. At the same time, cross-contamination is particularly common in the storage and transportation process. If different types of food share the same storage space or transportation tools, it is very easy for microorganisms to spread between them. In addition, the risk of contamination during transportation cannot be ignored. If transportation equipment is not thoroughly cleaned or improperly maintained, it may become a source of contamination; unclean transportation tools and inappropriate transportation conditions, such as exposure to harsh environments, may increase the risk of food contamination. During transportation, microorganisms may spread to the surface or inside of food through air flow, contact with water sources or indirect effects of contaminated equipment, causing contamination [5].

2.2. Common Food Contamination Microorganisms and Their Hazards

According to the type of microorganisms, common food contamination microorganisms include bacteria, fungi, viruses and parasites. Since food can often meet the nutritional conditions required for the growth of microorganisms, if it is not specially processed, all links in the food supply chain may be contaminated by various harmful microorganisms.

2.2.1 Bacteria

Bacteria, as one of the main sources of pollution, are numerous and potentially harmful. Common pathogens such as *Salmonella*, *Escherichia coli*, and *Staphylococcus aureus* have diverse existence and contamination pathways, posing a serious challenge to food safety. *Salmonella* is often found in meat, poultry, and processed products. *Salmonella* infection can cause serious gastrointestinal diseases, including diarrhea, fever, and abdominal pain [6, 7]. *Escherichia coli*, especially certain pathogenic strains (such as O157:H7), mainly exist in the intestines of animals and may contaminate water, soil, or food processing equipment through feces. This bacterium has strong survival ability and infection potential, and can cause a variety of inflammations including but not limited to diarrhea, dehydration, hypotension, and even urethritis, cystitis, peritonitis, etc [8]. *Staphylococcus aureus* is commonly found in high-protein foods such as dairy products, meat, and seafood. Its contamination is usually related to improper handling during food processing, poor storage conditions, or poor personal hygiene habits. *Staphylococcus aureus* can produce a variety of toxins, such as enterotoxins [9], which can remain in food even after the bacteria are killed, leading to food poisoning. The bacterial contamination mechanisms are complex and varied, mainly including rapid growth and reproduction under suitable environmental conditions, secretion of harmful toxins, and harming human health through direct infection. Under suitable temperature and humidity conditions, bacteria can reproduce rapidly, causing food spoilage [10].

2.2.2 Fungi

Fungal contamination is also very common in food microbial contamination, especially in the storage and processing stages of the food supply chain. Common food-contaminating fungal groups,

such as molds and yeasts, prefer to thrive in moist and warm environments. Mold is widely spread in the air in its spore form and can easily invade the surfaces of various foods with the help of natural factors such as wind, dust and other media. Yeast, on the other hand, prefers to live in food matrices rich in sugar and nutrients, such as fresh fruits, juices and vegetables. Under appropriate temperature and humidity conditions, these fungi can multiply rapidly, which not only accelerates the spoilage process of food, but may also lead to a significant decline in food quality. What's more serious is that some fungal species have the ability to produce harmful toxins, such as aflatoxins and gibberellins. These toxins pose a potential threat to human health. Long-term intake or high-dose exposure may induce acute or chronic poisoning, and even increase the risk of cancer [5].

2.2.3 Parasites

Parasites are an important component of microbial contamination, and their impact cannot be ignored. Common food contamination parasites are diverse, including but not limited to protozoa, nematodes and trematodes. Each type threatens human health with its specific living environment and transmission method [11]. Protozoa are a type of single-cell parasite that is commonly found in fresh fruits, vegetables and aquatic products. *Cryptosporidium* is a typical example. This tiny parasite can use contaminated water or food as a medium to invade the human body and cause cryptosporidiosis, affecting the health of the digestive system. Nematodes are more likely to hide in meat and seafood. For example, *Trichinella spiralis* infects animal muscles and forms cysts in them. Then, when eating undercooked meat, it enters the human body and causes serious diseases such as trichinosis. Therefore, ensuring that meat products are thoroughly cooked is a key measure to prevent such parasitic infections. Trematodes mainly live in freshwater fish and aquatic plants. If humans eat food contaminated by trematode larvae, they may contract trematodiasis. Such diseases not only affect the function of organs such as the liver, but may also cause a series of complications. Therefore, when purchasing and cooking aquatic food, special attention should be paid to the safety of its source and processing methods.

2.2.4 Viruses

The number of virus contamination sources may be relatively small, but their potential harm and transmission ability cannot be ignored. Common food contamination viruses, such as norovirus, enterovirus and adenovirus, can penetrate into the food chain through various pathways, posing a threat to public health. Among them, norovirus and enterovirus are the main culprits of acute gastrointestinal diseases. After infection, they can cause severe symptoms such as vomiting and diarrhea, affecting the patient's quality of life and may cause complications such as dehydration; adenovirus mainly infects the respiratory tract, but in some cases, it may also be transmitted through food as a carrier. The presence of these viruses in food not only directly endangers the health of consumers, but may also increase the risk of disease transmission and lead to mass infection events.

3. Chemical Hazards Faced by Pre-prepared Meals

Chemical hazards in food mainly refer to the risks posed by chemical substances that may exist in food and have adverse effects on human health. These chemical substances may come from natural ingredients of food, production and processing, environmental pollution, and other aspects [12]. According to whether they exist naturally, they can be generally divided into two categories: toxins and allergens that exist naturally in food, and chemical substances used or contacted in the food supply chain. The contamination pathways of the latter are similar to the transmission pathways of microbial contamination, so we will not elaborate on them here.

3.1. Production of Raw Materials for Pre-prepared Meals

3.1.1 Natural Toxins and Natural Allergens

Natural allergens refer to regular ingredients contained in food itself that can induce allergic reactions in specific groups of people, such as protein in soybeans, specific proteins in shrimps, and

certain allergenic factors in lamb. Natural toxins refer to toxic ingredients originally contained in food, such as tetrodotoxin in pufferfish and solanine in Solanaceae plants. The accumulation of these natural toxins and allergens in the human body not only disrupts the balance of microbial communities in the body, but also affects the normal metabolism, and its potential hazards cannot be ignored. They may directly irritate the gastrointestinal mucosa and cause discomfort; in key organs such as the heart and lungs, they may act as pathogenic factors, aggravating inflammation or damage; they may mistakenly activate phagocytes in the immune system, leading to excessive immune response; in the long run, they may also become a factor in increasing the risk of tumors and cancer.

3.1.2 Pesticide Residues

During the planting and production stage of plant raw materials, pesticides are sprayed to reduce diseases and various types of pests. If they are not handled in time, the pesticides remaining in the raw materials will exceed the maximum residual level (MRL) [13], which will have adverse effects on the human body. Specifically, it can cause acute toxic reactions, that is, cause obvious health damage in a short period of time; at the same time, long-term low-dose exposure may induce chronic toxicity and cause lasting damage to the internal organs of the body. In addition, these residues can also interfere with the normal function of the nervous system and have adverse effects on the individual's behavior, cognition and even emotional state. More seriously, pesticide residues also have genetic toxicity, including causing developmental deformities, gene mutations and increased risk of cancer, posing a long-term threat to the reproductive system and the healthy growth of offspring [13].

3.1.3 Veterinary Drug Residues

In the pre-prepared food market, meat pre-prepared dishes such as poultry, livestock, and fish account for a large proportion [14], so the management of veterinary drug residues cannot be ignored. Frequent use of drugs in high-density farming models, use of banned drugs, uncontrolled dosage, abuse of antibiotics, and improper use of drugs before slaughter can easily lead to excessive veterinary drug residues in animals, thereby affecting the overall safety of pre-prepared foods.

3.1.4 Heavy Metal Pollution

Heavy metal pollution is another major hazard of pre-prepared food ingredients. Heavy metal elements are difficult to degrade, highly toxic, and highly concealed. The main heavy metal pollutants include mercury, cadmium, lead, copper, chromium, nickel, and arsenic [15]. If industrial "three wastes" are not properly treated, they will pollute water sources and soil after discharge, and then enter crops and animals through bioaccumulation, contaminating the raw materials of pre-prepared food, causing the heavy metal content in pre-prepared food to exceed the standard. After entering the human body through the food chain, it will cause damage to the kidneys, nerves, bones, muscles, and other parts of the human body.

3.2. Pre-prepared Food Processing

3.2.1 Pollution by Illegal Additives

In order to improve the appearance, taste or extend the shelf life of pre-prepared dishes, unscrupulous businesses may illegally add illegal substances, such as adding borax to enhance the toughness of meatballs and using formaldehyde to preserve aquatic products. These behaviors seriously threaten the health of consumers and require increased supervision.

3.2.2 Food Additives

According to the latest regulatory requirements, the addition of preservatives is explicitly prohibited in pre-prepared dishes, but the rational use of antioxidants, colorants, colorants, flavor enhancers and other additives still needs attention. Especially in pre-prepared seafood dishes, the large-scale use of compound additives needs to be strictly controlled to prevent health risks caused by excessive amounts.

3.2.3 Hazardous Substances Generated during Processing

Some pre-prepared dishes use roasting, grilling, frying and deep-frying during production and processing, which can produce carcinogens such as polycyclic aromatic hydrocarbons and heterocyclic amines, such as benzo[a]pyrene and heterocyclic amines, which are listed in the "List of Class 1 Carcinogens" published by the World Health Organization's International Agency for Research on Cancer. These substances pose a long-term threat to human health, and the processing technology needs to be optimized to reduce their generation [16].

3.2.4 Contamination of Packaging Materials

The pre-prepared food packaging materials vary, and plastic materials, aluminum foil materials, electroplated tin thin steel sheet materials, etc are all commonly used materials. Under high temperature conditions, harmful substances in packaging materials that come into contact with food may migrate into the food [17]. This is particularly common in products such as self-heating hot pots, and special attention should be paid during the heating process. In addition, the packaging materials of seasoning packets may also release harmful substances under certain conditions (high acid, high fat), so the safety of the packaging materials must be ensured.

3.3. Storage and Transportation of Pre-prepared Meals

Pre-prepared food has a long shelf life, and refrigeration and freezing are the main means of storage and transportation. However, if the temperature is not properly controlled during storage and transportation, it will accelerate the deterioration of food quality, such as fat oxidation and protein decomposition, leading to the deterioration of physical and chemical indicators affecting the overall quality and safety of pre-prepared food. Therefore, strict storage and transportation management is crucial [18].

4. Conclusion

This article outlines the contamination pathways of microorganisms and harmful chemicals in the industrial chain of prepared dishes from raw material selection to factory production and processing, then to storage and transportation, and finally to the consumer terminal, and lists common harmful substances. The purpose is to point out the sources of most potential hazards for practitioners in the prepared vegetable industry, inspire workers in the industry chain to prevent and control risks in a targeted manner, help build an all-round, multi-link food safety prevention and control system, and promote the healthy and sustainable development of the prepared vegetable industry. Although this article does not fully apply the HACCP system to analyze the risk points of food production and processing, it can still extract from the article generally applicable prevention and control guidelines for each link: 1) Strengthen the control of the source of raw materials, optimize storage conditions, and reduce Initial contamination; 2) Implement strict microbial and chemical residue detection and control measures in all key links of processing, warehousing and logistics to ensure operational specifications; 3) Actively explore and apply efficient, economical and convenient technologies and equipment to reduce technical implementation difficulty and cost, and improve the microbial and chemical safety level of the entire industry chain. If these measures can be implemented, food safety contamination in prepared dishes can not only be effectively prevented and controlled but the quality and market competitiveness of prepared dish products can also be significantly improved, helping the prepared dish industry move towards a more glorious future.

References

- [1] Qi Zhiming, Wang Pei. Broad Prospects for the Development of the Pre-cooked Food Industry. People's Daily, 2023, p. 010.
- [2] Zhou Yan, et al. Semi-quantitative Risk Assessment of Major Pathogens in Raw Aquatic Products. Food Research and Development, 2015, 36(4): 108-114.

- [3] Wang Xuan, Zhu Ling. Application of HACCP System in Processing Refrigerated Convenience Food in Central Kitchen: A Case Study of Braised Meat Rice Bento. *Meat Industry*, 2022(09): 28-35.
- [4] Huang Cui, et al. Investigation and Analysis of Common Bacterial Contamination in Lettuce and Water-soil Environment in Vegetable Base of Daoli District, Harbin. *Food Safety Guide*, 2022(29): 51-56.
- [5] Zhou Daorong, Liu Shi, Yang Jimei. Analysis of New Strategies for Preventing and Controlling Food Microbial Contamination and Technological Innovation. *Modern Food*, 2024, 30(8): 145-147.
- [6] Wang Yuyan, et al. Investigation and Analysis of Salmonella Contamination in the Chicken Production Chain. *China Poultry*, 2023, 45(2): 77-82.
- [7] Li Na. Research Progress on the Detection and Prevention of Salmonella. *Food Safety Guide*, 2022(11): 178-180.
- [8] Yang Pu, Ju Feng, Zhang Lizhen. Survival Strategies and Governance Methods of Foodborne Pathogenic Bacteria in Soil. *Journal of Agro-Environment Science*, 2022, 41(12): 2694-2704.
- [9] Li Yi. Research Progress on Staphylococcus Aureus and Its Enterotoxins. *Chinese Journal of Health Laboratory Technology*, 2004, 14(4): 392-395.
- [10] Chen Zhiqiang. Analysis of Microbial Contamination in Frozen Food in Supermarkets. *China Food Industry*, 2022(22): 28-29.
- [11] Wei Jiaojiao, Huang Xihai. Application of ATP Bioluminescence Amplification Method in Detecting Food Microbial Contamination. *Food Safety Guide*, 2021(28): 84-85.
- [12] Tan Muhua, Yuan Di, Zhang Hao. Chemical Hazards in Food. *Food Industry*, 2017(06): 55.
- [13] Tan Guolin. Analysis and Prevention of Chemical Hazards in Food. Shanghai, 2009: 230-235.
- [14] Jin Kenan, et al. Research Progress on the Safety and Control of Meat-based Pre-cooked Foods. *Modern Food Science and Technology*, 2023, 39(2): 110-118.
- [15] Ke Xuqing, Xu Zhaobo, He Siting. Research Status of Chemical Hazards in Traditional Foods in Guizhou. *Modern Food*, 2023, 29(06): 146-148.
- [16] Li Huilin, et al. Research Progress on the Formation Rules of Heterocyclic Amines in Xinjiang Roasted Lamb Kebabs. *Journal of Food Safety and Quality Inspection*, 2024, 15(7): 45-53.
- [17] Shui Xiaolin, et al. Development Overview and Trends of Pre-cooked Food Packaging Technology. *Packaging Engineering*, 2023, 44(13): 132-140.
- [18] Zhang Ruirui. Risk Analysis of Chemical Contamination in Pre-cooked Foods. *Food Safety Guide*, 2024(15): 10-12.