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Review

Research and Development Status of Prepared Foods in China: A Review

Bo Yi and Hengyi Xu *

State Key Laboratory of Food Science and Resources, Nanchang University, Nanchang 330047, China; 7904120019@email.ncu.edu.cn

* Correspondence: kidyxu@163.com or hengyixu@ncu.edu.cn

Abstract: In recent years, due to the influence and promotion of several factors, the Chinese market demands for prepared foods have grown rapidly. However, there are still many problems with Chinese prepared food. As China's prepared foods are still at an early stage of development, there are problems such as vague concepts, outdated processing techniques and equipment, imperfect, unclear and inconsistent national standards, and prominent safety risks. The existence of these problems hinders the high quality and stable development of prepared foods. Thus, to meet the further development of prepared foods, it is necessary to conduct further analysis and research on the concept and boundary of prepared foods, set the Chinese national standards for prepared foods further, reform and upgrade the processing technology and equipment of prepared foods, and develop the safety control management system of prepared foods to promote the high-quality development of the prepared foods industry and provide a solid foundation for the further development of this industry. In this paper, the research progress of prepared foods' processing techniques and the difficulties of industry development have been reviewed. In addition, an outlook on the future of prepared foods is provided, with a view to giving some reference for the innovative and stable development of prepared foods in the future.

Keywords: prepared foods; processing technology; development difficulties; research trend

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1. Introduction

Currently, there is no clear definition of prepared foods. However, the industry generally considers prepared foods to be agricultural, livestock, poultry, and aquatic products as the main raw materials, which use standardized flow operations, made by pre-processing, pre-cooking, and pre-packaged finished or semi-finished products [1]. There are various types of prepared foods, such as meat prepared foods, vegetable prepared foods, cereal prepared foods, frozen prepared foods, and ready-to-eat prepared foods, which are commonly available in the market. Prepared foods can be divided into categories according to different classification perspectives, covering almost the entire food industry. In recent years, with the improvement of modern living standards and socio-economic development, people's diet has become more healthy, nutritious, diversified, varied in flavour, and convenient. However, the rapid growth of society has also brought about a fast-paced, high-stress lifestyle, which has resulted in considerable changes to people's lives, consumption habits, and environment [2]. This lifestyle has led to the rapid development of prepared foods and the gradual expansion of prepared foods from supplying restaurants to supplying households, bringing tremendous business opportunities to the prepared foods industry. In addition, with the continuous development of the catering industry supply chain, food processing technology, logistics and transportation systems, and cold chain technology, the scale and systematization of the prepared foods industry have been greatly developed and improved [3].

As of 2022, the prepared foods' market size reached USD 61.14 billion in China [4], with an average annual growth rate of 25%. The market size is expected to break through

to USD 144.8 billion in 2026 [5]. Nevertheless, the current Chinese prepared foods' market penetration rate is only 10% to 15%, which is expected to increase to 15% to 20% in 2030. Referring to the Japanese market, which has a similar dietary structure to China, the proportion of prepared foods reaches more than 60%, so we speculate that China's prepared foods market could reach around USD 400 billion when it matures. Thus, the Chinese prepared foods market still has vast room for development and may even grow at a higher rate than expected in the future. The market scale and forecast of China's prepared foods industry from 2019 to 2026 is shown in Figure 1.

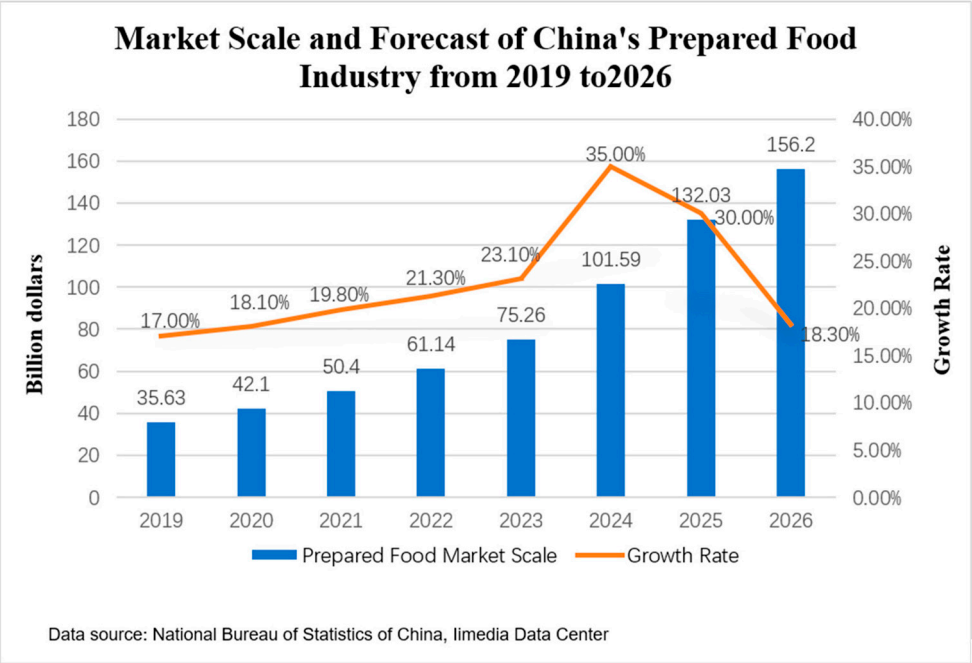

Figure 1. Market scale and forecast of China's prepared foods industry from 2019 to 2026.

However, there are still many problems in the development of prepared foods in China which need further study. The prepared foods in Japan, Europe, and the United States have been long developed, and in these countries, people have formed more complete and mature market and relevant industry systems. Meanwhile, much technology and more standards have also been developed, which are more suitable for their diets and lifestyles than in many decades. Though China is a large-territory country, with many delicious and traditional foods, which are varied and with regional characteristics, there is an obvious gap between the prepared foods of China and the Western countries' average in development degree [6]. Furthermore, the huge markets and scale economies' effects of prepared foods in China were not recognized and utilized in the past. As a result, prepared foods in China are still in the beginning stage of their development. There are many problems about explaining their vague concepts, and a lack of impeccable national standards and processing equipment, along with safety hazards. Therefore, to keep up with the average on the prepared foods of the developed countries and to minimize the huge gaps between the prepared foods, there should be comprehensive consideration and much effort devoted. There is no doubt that technical studies and product development, equipment innovation, and consumer demands are crucial to promote the healthy and sustainable markets of the prepared foods of regions. In those developed countries with impeccable food logistics systems, warehousing and distribution infrastructure, and the perfect standard and safety and quality control system, prepared foods have been greatly studied and developed over many decades [7]. In this paper, we review the development history and influencing factors of prepared foods, provide a comprehensive review of the current situation, and research the progress and problems of the development of prepared foods that have been reviewed, especially analysing prepared foods in China. This work aims to identify current gaps of

prepared foods between China and Western countries and hopes to provide some helpful references for the development and progress of the domestic prepared foods industry.

2. The Formation of Prepared Foods

As early as 1880, Nicolas Appert invented the canning process, which led to the world's first prepared foods of "canning". His main objective was to offer consumers, especially seamen, preserved foodstuffs still having the appearance and properties of fresh fruits and vegetables [8]. Commercial canning appeared in England in 1810, heralding the formal commercialization of prepared foods. Later, Birdseye invented rapid freezing technology to expand the distribution range of prepared foods, which gradually developed into more food categories, such as frozen vegetables, soft canned foods, refrigerated foods, and fast foods [9]. Along with the development of technology and economy in the early part of last century, prepared foods developed rapidly in the United States, Europe, Japan, and other developed countries [10]. The industry grew and matured in the 1990s [11]. A more specific history of the development of prepared foods is shown in Figure 2.

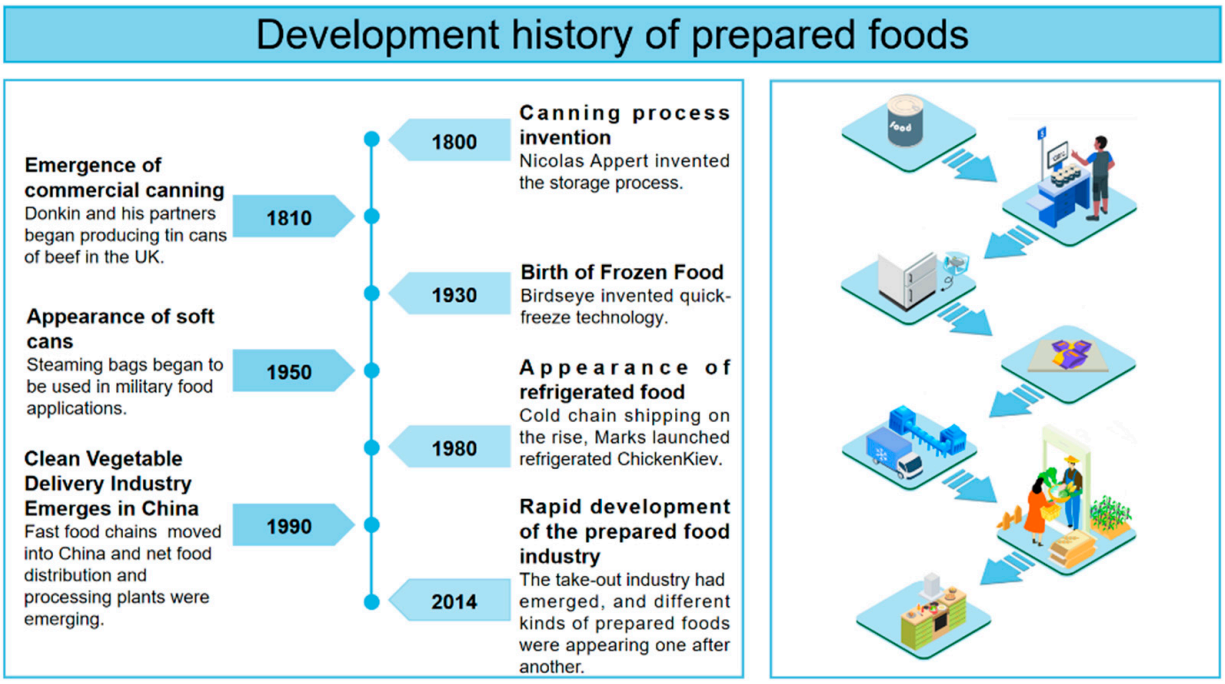

Figure 2. The development history of modern prepared foods.

Moreover, the development of prepared foods in China was relatively late, because such foods have only started to develop in recent years. The development history of China's prepared foods mainly includes three stages: Phase I—the starting phase. Around 2000, prepared foods enterprises that mainly produced semi-finished food products began to appear, and the industrialization of prepared foods began. However, the overall development of the prepared foods industry grew slowly due to the backwardness of Chinese cold chain logistics, quick-frozen technology, and food processing technology at the early stage of industry development. Phase 2—stagnation phase. As of 2013, due to the slow development of Chinese food processing technology, such as thermal processing, sterilization, storage, packaging, cold chain technology, etc., the development of the prepared foods industry had stagnated, and there had been no significant breakthrough. Phase 3—explosive growth phase. Since 2014, the emergence of the take-out sector has facilitated the development of the prepared foods industry in the catering industry [12]. Prepared foods have made great progress in the past few years.

In recent years, the accelerating pace of social life has resulted in working people not having enough time to prepare meals, and the tedious and time-consuming steps of

buying, washing, chopping, and cooking have proved difficult for the young. Naturally, most of them also are not good cooks. Therefore, they seek help from the outside to comfort their hunger. At this point, prepared foods, which are perfectly suited to their requirements, emerged in China. At the same time, people's lifestyles have changed dramatically in the post-pandemic era, and the rapid growth of the take-out industry has led to a surge in demand for convenience foods [13], accelerating the market formation of prepared foods [14]. Moreover, the rising income level of residents has prompted a reconfiguration of the household consumption scene, accelerating the industrialization of the prepared foods industry. Urban and rural residents' consumption of food has changed from survival consumption to healthy, enjoyable, and high-quality consumption [15], and from the solution of subsistence to a proper, healthy, and safe diet, which provides a huge consumer market for the prepared foods industry and lays the economic foundation for the healthy development of prepared foods [16]. In addition, breakthroughs in key technologies have also applied for the technical foundation for the rapid development of prepared foods. The breakthrough of novel targeted bacteria reduction technology, flavour development and maintenance technology, fast precooling technology, map, and other technical equipment has provided a guarantee for the stable quality of prepared dishes during industrial processing, storage, sales, and consumption [17]. The strengthening of the distribution capacity of cold chain logistics [18] has driven the development of the industry. The storage time of prepared foods can be significantly extended, and the freshness of the foods can be maintained to the maximum [19]. Under the cold chain logistics distribution system, prepared foods enterprises expand the scope of distribution, improve the efficiency of product distribution, and expand the market coverage of prepared foods while ensuring food safety. Above all, all the actors mentioned above have to some extent promoted the emergence and development of prepared foods in China.

3. The Classification of Prepared Foods

Currently, there is no clear industry definition for the classification of prepared foods. However, there are many classifications of prepared foods in the prepared foods industry according to the different scenarios of consumption, processing methods, and preservation methods of prepared foods, which are classified in various ways [11].

According to different consumption scenarios, prepared foods can be divided into breakfast refreshments, dinner dishes, and snack foods [20]. Breakfast refreshments include bread, spaghetti, and jam. Dinner dishes are usually served as the main meal and need to be reheated or cooked. Snack foods are mainly small, packaged foods that are sterilized to achieve "Commercial Sterility" and can be consumed as snacks, such as beef jerky and dried apple slices. This classification can meet the needs of consumers for prepared foods in different scenarios in their lives [11].

When the different ways of cooking or reheating prepared foods are used as a classification principle, prepared foods can be divided into four types [21]. They are ready-to-heat foods, ready-to-cook foods, ready-to-eat foods, and ready-to-use foods. Ready-to-heat foods are foods that need to be heated so that they can be consumed, such as quick-frozen dumplings, quick-frozen glue pudding, and instant noodles. Ready-to-cook foods are foods that require simple cooking to be produced, such as marinated steak, mainly according to a consumer's preference to control the number and type of seasoning packets added to the simple cooking. Ready-to-eat foods are ready to eat out of the bag without processing or reheating and include dried bean curd, dried fish, and canned goods. Ready-to-use foods, also known as fast foods, mean that the net vegetables, net meat, and other auxiliary ingredients are divided into portions and finally combined to form fried vegetable buns, such as soup combinations and small fried vegetable buns. The classification of prepared foods based on cooking or reheating methods is a more accepted way of classification in the mainstream of the prepared foods industry today. It is effectively used in the processing and production of prepared foods.

According to their different preservation conditions, prepared foods can be divided into frozen foods, refrigerated foods, and normal temperature foods. Different refrigerated conditions have different effects on foods [22]. The storage temperature of frozen foods is below 0 °C, generally −18 °C, and their representative products are mainly frozen pills, frozen meats, and frozen dumplings. Frozen foods are generally not sterilized, in a non "Commercial Sterility", and their shelf life in the frozen state can reach six months to a year, and some products last even longer. The preservation temperature of refrigerated foods is 0–5 °C, with their representative products net vegetables, marinated beef steaks, and marinated chicken steaks. Refrigerated foods are generally unsterilized, in a non "Commercial Sterility", and generally have a shelf life of 1 to 3 d in the refrigerated state [23]. The storage temperature of normal-temperature foods is room temperature, and their representative products are small packages of marinated foods. Normal-temperature foods are sterilized, in a "Commercial Sterility", with a shelf life of six months to a year at room temperature [24]. This classification is often used in the preservation and transportation of prepared foods, which is essential to maintain flavour and food safety stability during the preservation and transportation process. Freeze-chilling involves freezing and frozen preservation, followed by thawing and chilled storage. It may have logistic benefits for food processors because it enables "chilled" products to reach more distant markets and facilitates bulk production of these foods.

In summary, there are many classifications of prepared foods according to the different scenarios of consumption, processing methods, and preservation methods, which are classified in various ways. However, compared to advanced prepared foods' classifications, most of the classifications of Chinese prepared foods are developed by enterprises or individuals, and there is no unified standard for the industry [25]. To a certain extent, this will restrict the development of Chinese prepared foods, and the industry practitioners need to work together to form a unified classification standard.

A more complete and detailed classification of prepared foods is shown in Table 1.

Table 1. The classification of prepared foods.

Principle of Classification		Different Ways of Cooking	References
Type and main products	Ready-to-heat food	Ready-to-eat food is ready to eat right out of the bag, with no processing or reheating required, such as canned dried tofu and beef jerky.	[26,27]
	Ready-to-cook foods	Ready-to-cook food includes products that require heating before consumption, such as frozen dumplings, frozen balls, and instant noodles.	
	Ready-to-eat food	Ready-to-eat food requires simple cooking and is ready to eat (mainly according to consumers' preferences to control the type and amount of seasoning), such as marinated beef steak.	
	Ready-to-use food	Ready-to-use food is a stir-fry package made by manually configuring various food ingredients, such as soup combination package and small stir-fry combination package.	
Type and main products	Frozen foods	Storage temperature below 0 °C, generally −18 °C. Representative products are frozen balls, dumplings, and so on. They are non-commercially sterilized and have a shelf life of six months to a year in the frozen state, with some products lasting even longer.	[28,29]
	Refrigerated Food	The storage temperature is generally 0–5 °C. Representative products are refrigerated vegetables, pickled steak, and so on. They are non-commercially sterile and generally have a shelf life of 1–3 d when refrigerated.	
	Normal temperature foods	The storage temperature is normal; representative products are small packages of pickled food and so on. They are commercially sterile and have a shelf life of six months to one year at room temperature.	
Type and main products	Cereal prepared foods	Their raw materials are mainly grains, such as wheat, rice, corn, sorghum, sweet potato, yam, and so on. Representative products are bread, frozen pastry, oat groats, and so on.	[30–32]
	Livestock and poultry prepared foods	Their raw materials are mainly livestock and poultry meat, such as chicken, duck, beef, pork, and so on. Representative products are mainly pickled steak, ready-to-eat cured vacuum-packed turkey breast, and so on.	
	Aquatic prepared foods	Their raw materials are mainly fish, shrimp, shells, algae, and so on. Representative products are canned fish and ready-to-eat seaweed.	
	Fruits and vegetables prepared foods	Their raw materials are mainly fruits and vegetables, such as yellow peach, orange, lychee, cabbage, and so on. Representative products are canned yellow peach, pickles, sauerkraut, and so on.	
Type and main products	Breakfast refreshments	They are prepared foods served for breakfast. Representative products include sandwiches, bread, cookies, buns, and so on.	[33]
	Dinner dishes	They are usually served with a proper meal	
	Snack food	They are mainly sterilized to achieve a commercial sterile state of small packaging food, such as potato chips.	

4. The Ingredients of Prepared Foods

4.1. Livestock and Poultry

The raw material sources of livestock and poultry mainly come from artificially raised pigs, ducks, chickens, geese, sheep, cattle, and so on (Figure 3). Most livestock come from the ecological standard of farms, and were raised until meeting the needs of the demands and regulations before being sent to the central kitchen [34]. Those livestock and poultry will then be executed in a proper manner, and to minimize their suffering as much as possible. Those raw materials will be pretreated, including cleaning, slitting, tumbling, blanching, and marination [35]. After these pretreatments, it can result in the raw materials of livestock and poultry forming a unique flavour, improve the taste and quality of meat products, inhibit the activities of some microorganisms, and slow down the spoilage of meat at the same time, thus extending the shelf life of livestock and poultry prepared foods [36].

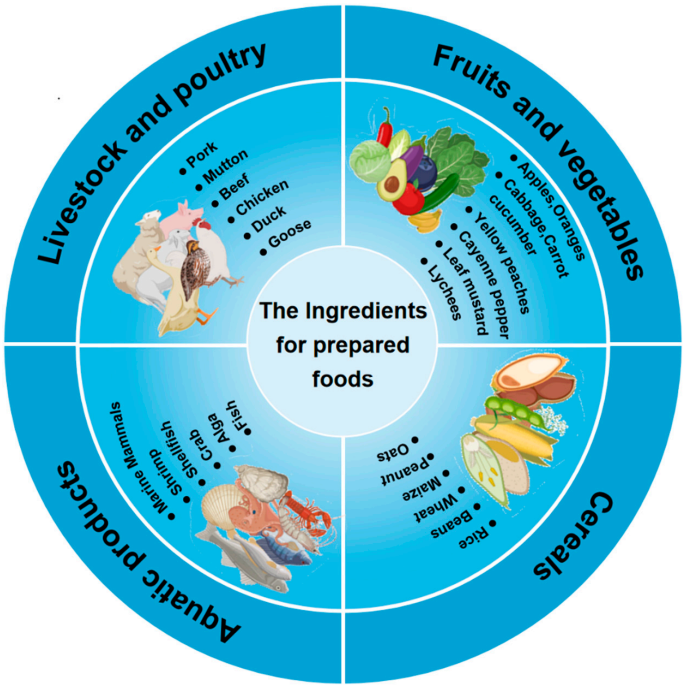

Figure 3. The ingredients for prepared foods.

4.2. Aquatic Products

The raw material sources of aquatic prepared foods are mainly fish, shrimp, shellfish, algae, and so on (Figure 3). Fresh fish, shrimp, shells, algae, and other aquatic products are processed in a modern standardized central kitchen [37]. The raw aquatic materials will be dealt a series of treatments, including deodorization, deacidification, tenderization, and bacterial reduction in the processing plants. Before those aquatic products are placed in the supermarket or on the dining table, they will meet other pretreatments, such as fermentation, drying, surimi, smoking, cooking or non-cooking, packaging, and other processing links [38]. They are then ready for consumption after simple heating or cooking. Aquatic food has always been very popular among consumers, because fish, shrimp, shellfish, and other aquatic animal products are delicate and juicy, with the outstanding nutritional characteristics of high protein, low fat, and low calories. In addition, their protein is rich and comprehensive in high-quality essential amino acids. Furthermore, algae are rich in carbohydrates, trace elements, and dietary fibre [39]. Therefore, easy-to-prepare-and-carry, high-quality, and nutritious aquatic prepared foods are more popular among consumers and include canned seafood, ready-to-eat seaweed, and canned salmon caviar.

4.3. Fruits and Vegetables

Prepared foods of fruits and vegetables are ubiquitous in daily life. The dehydrated vegetables in the vegetable packets of instant noodles are a type of prepared foods, the usual fruit salad [40] and kimchi are also a type of prepared foods, and the canned yellow peaches and oranges that everyone has bought on the supermarket shelves are also a type of prepared food. The main sources of raw materials for fruit and vegetable prepared foods are vegetables and fruits. Vegetables include radishes, carrots, cucumber, cabbage, cauliflower, mustard, and other categories; fruits include apples, yellow peaches, lychees, oranges, strawberries hawthorn, and other types (Figure 3). Prepared foods of fruits and vegetables are generally available as ready-to-eat net dishes, canned, and pickles. Fruits are rich in sugars, vitamins, trace elements, dietary fibre, and other essential nutrients [41], but fruits are not suitable for preservation. Fruits can be made into prepared foods through vacuum cooling technology and low-temperature preservation technology [42], which can greatly extend their shelf life and broaden their sales market. Vegetables are also rich in vitamins and trace elements and can be made into prepared foods to satisfy people's need for more choices of different vegetables [43].

4.4. Cereals

Prepared cereals are also widely distributed in people's diets, and are usually made by grinding, kneading, shaping, forming dough, fermenting, steaming, baking, and other processing of cereal raw materials into prepared food or directly processed with other ingredients. For example, the popular frozen meatballs and frozen dumplings in supermarkets [44] are prepared foods made from wheat or rice milled into flour with fillings. The richly scented, golden-coloured bread in bakeries is also prepared food made from grain-milled flour that has been fermented and baked. Another example is the filled cereal-based porridge sold in stores [45], which is also prepared food made from various grains, such as millet, oats, rye, wheat starch, and kidney beans. Due to their high protein, fat, and starch content, grains are the main source of plant protein for humans. Thus, cereals are widely used in the preparation of prepared foods (Figure 3). The main cereal ingredients used in cereal prepared foods are wheat, corn, sorghum, soybeans, oats, rye, and other grains [46].

4.5. Others

In addition to the above four categories of prepared food ingredients, there are several other prepared food ingredients [47], such as artificial food ingredients, which include margarine, modified starch, artistic meat, artistic eggs, synthetic syrups, and so on [48]. Products made from raw materials, such as artificial food processed by scientific means, are called synthetic prepared foods. Synthetic prepared foods are not made from chemical ingredients. They are based on the nutritional composition of bionic natural food to select common food containing similar ingredients as components and make a variety of bionic imitation foods [49], such as imitation crab sticks, sausage, luncheon meat, synthetic beef, and artistic food additives (Figure 3). Although consumers still hold a suspicious attitude towards artistic food, it offers a potential solution to consumer demand for meat, given global environmental concerns, public health problems, sustainability, and animal welfare concerns.

The ingredients for prepared foods come from a wide range of sources and cover numerous areas, such as the breeding of livestock, poultry, aquatic products, and crop planting. Compared to advanced prepared food ingredients, the quality of China prepared food ingredients may be uneven and inconsistent. This is mainly because the planting methods of crops are not mechanized or standardized, and the breeding methods of livestock, poultry, and aquatic products are not standardized in China, which may cause instability and fluctuations in the quality of ingredients for China prepared foods [50].

5. Production Process of Prepared Foods

Due to the explosion of prepared foods, the prepared food industry has grown by leaps and bounds, and the number of prepared food companies continues to increase [51].

The processing technology of prepared foods is also being upgraded. For example, in the past, most of the production of prepared foods was mainly achieved in family workshops, small stores, and small factories, and most of the production process was performed by hand. Marination, as in the case of prepared meat, is still traditionally performed manually with salt curing in vats, which is difficult to effectively control the salt and water content distribution in prepared meat [52]. Pretreatment processes such as sorting and washing raw materials for fruit and vegetable prepared foods are carried out manually. In addition, it is also difficult to guarantee the food safety of the products in production and transportation. Furthermore, with the development of modern technology, the production of prepared foods has become intelligent, mechanized, and industrialized [53]. Prepared foods' raw materials pretreatment, thermal processing, sterilization, packaging, and other processes benefit from the development of new technologies such as intelligent fruits and vegetables sorting technology, thermal processing appliances, new sterilization technology, and new intelligent packaging technology, which become intelligent, efficient, and industrialized [54].

The processing of prepared foods varies according to the quality requirements of different dishes, cooking methods, packaging, preservation, storage, and transportation conditions [54]. This review divides the whole process of processing and manufacturing of prepared foods into three parts: pretreatment of raw materials of prepared foods at the "Front end", processing and manufacturing of prepared foods at the "Mid-range", and sterilization, preservation, and transportation of prepared foods at the "Ends".

5.1. Pretreatment of Raw Materials of Prepared Foods at the "Front End"

First of all, the pretreatment of prepared food ingredients is at the "Front end", and the pretreatment processes of prepared food ingredients in central kitchen processing (The central kitchen concept is a new trend in the food industry, where centralized preparation and processing of fresh foods and the distribution of finished or semi-finished products to catering chains or related units take place) include cleaning, slitting, enzyme inactivation, sterilization [37], blanching, superheated steam treatment, removal of fishy odour, and acid drainage. Among them, the slitting, cleaning, and enzyme inactivation process is mainly used for the pretreatment of fruits and vegetables' prepared food materials. After the raw materials are harvested, they need to be cleaned, slit, and enzyme inactivated immediately to prevent the fruits and vegetables from missing the processing maturity due to the ripening effect of their own enzymes, while achieving the purpose of colour protection, crispness retention, reducing nutrient loss, and extending the shelf life. The process of slitting and washing is carried out not only by using fruit and vegetable sorting machines and fruit and vegetable washing machines, but also by manual processing. Enzyme inactivation is mainly achieved through non-thermal techniques [55]. At the same time, the processes of blanching, superheated steam, acid drainage, and removal of fishy odour are mainly used for the pretreatment of raw materials for animal prepared foods. Similarly, to the production of pickled beef chops, the raw meat needs to be drained, then blanched or subjected to superheated steam treatment. The purpose is to remove the residual blood and surface oil in the meat, and at the same time remove the odour of the meat [56]. The number of blanching and the duration of blanching times can affect the taste, colour, flavour, and nutritional quality of meat products [57]. The most suitable number of blanching times and the duration of blanching times differ for different meats; for example, chicken has the lowest concentration of odour substances after blanching twice. In addition, studies have shown that superheated steam can also be used to remove odour substances from meat and reduce the loss of juices associated with blanching compared to traditional blanching treatments [58]. The removal process of fishy odour is mainly used for pretreatment of raw materials for aquatic prepared foods [59]. Due to the high moisture content and active tissue enzymes in aquatic raw materials, it is easy to produce a fishy taste that is not conducive to sensory acceptance, which seriously restricts the development of their fresh marketing and processing. The means of removing fishy odour usually include

physical methods (masking, adsorption, embedding, and irradiation), chemical methods (organic solvent extraction, acid and alkali salt method, antioxidant method, and ozone method), biological methods, and composite methods.

5.2. Processing and Manufacturing of Prepared Foods at the "Mid-Range"

The next step is the processing and manufacturing of prepared products at the "Mid-range", which is a key step in the processing and production of prepared foods and involves heat treatment and non-heat treatment processes for prepared foods. Heat treatment is mainly a way to cook livestock and poultry meat, which can denature the proteins in meat and decompose them into smaller protein molecules to promote the absorption of proteins and other nutrients by the human body, and heated food is easier to store and can extend the shelf life of livestock and poultry meat. There are many ways of heat treatment, and different heat processing methods can have different effects on the taste, flavour, and nutritional quality of livestock and poultry meat [60]. The main heat treatments are boiling, steaming, low-temperature vacuum heating, microwave heating [61], baking, and deep frying [62]. Steaming and boiling are common heat processing techniques in home cooking, can retain the maximum amount of nutrients in meat, and are one of the most suitable and healthy processing methods [63]. Sous vide cooking processes on tenderness is a technology that has received attention recently. It is a thermal processing technology in which vacuum-packed livestock and poultry meat is steamed in a water bath at a set temperature and time in a container, with the advantage of improving the tenderness and colour of the meat, slowing down oxidative deterioration, and retaining vitamins, minerals, and antioxidants [64]. Stir-frying, baking, and deep-frying is the processing method for cooking and drying foods, which is the process of heating and rapidly maturing foods by placing them in high-temperature fats. Stir-frying, baking, and deep-frying can kill microorganisms in foods and extend the shelf life of foods while improving the flavour and nutritional value and giving foods a unique golden colour. Stir-fried, baked, and deep-fried prepared foods mainly include fried fish skins, potato crisps, bread, and roasted argan kernels. The main equipment used are air fryers, woks, and roasters. Non-heat treatment mainly includes tumbling, marination, fumigation, drying, and so on. Tumbling and fumigation are mainly used for the processing of livestock and poultry prepared foods that can be stored for long periods [65]. Tumbling is performed through a mechanical action carried out by the tumbling equipment, so that the meat is constantly tumbled and impacted in the drum. It destroys the muscle fibres and softens the muscle tissue structure, which in turn improves the tenderness of the meat, increases its curing efficiency, and achieves the effect that improves the colour, flavour, tenderness, and other quality characteristics of meat products [66]. The traditional tumbling process has been widely used in the processing of livestock and poultry prepared foods. New tumbling processing technologies are also being used, such as variable pressure tumbling, ultrasonic-assisted tumbling [67], ultrasonic-assisted variable pressure tumbling, and ultra-high-pressure synergistic tumbling [68]. Marination not only increases the shelf life of meat, but also improves the colour, flavour, and nutritional quality of meat [69]. Traditional marination methods include wet marination and dry marination, which is mainly through the addition of large amounts of salt to prevent the spoilage of meat and prolong the shelf life [65], but this practice is prone to low salt penetration efficiency and long curing time. In the production process of making raw cured meat products, physicochemical changes (dehydration and changes in colour, hardness, pH, and water activity) and chemical changes (changes in NaCl content and degradative processes of proteins and lipids) take place. These changes are responsible for the sensory qualities of the final product. However, high salt content is also prone to increase the risk of chronic diseases [70]. Thus, with the rapid development of prepared food enterprises and the upgrading of prepared food production technology, new types of marination technology were born. The current new marination technologies mainly include static pressure marination technology, vacuum tumbling marination technology, ultrasound-assisted marination technology, and ultra-

high-pressure marination technology [71]. Fumigation can also inhibit spoilage of prepared foods and extend their shelf life. Fumigation is mainly divided into cold fumigation and hot fumigation. The difference between these two products in terms of sensory quality and stability determinants mainly include two parts: the saturation of smoke composition and the degree of drying of raw materials. Smoked prepared foods are characterized by a simple manufacturing processes, are nutritious, have a unique flavour, and are easily consumed [72], and the main products are smoked cheddar cheese, smoked mackerel, smoke-flavoured chicken rolls, and so on [73]. The main fumigation equipment is smoke-consuming stoves. Drying is mainly used in the processing of cereal prepared foods, and there are two types: natural drying and artificial drying. Drying removes water from prepared food ingredients by natural air or drying equipment to reduce the ingredients' water activity, inhibit spoilage, and extend their shelf life while supplementing them with flavourings to impart unique flavours to dry prepared foods [74]. The main dry prepared foods are dried carrot chips, freeze-dried strawberries, banana crisps, cereals, and beef jerky.

5.3. Sterilization, Preservation, and Transportation of Prepared Food at the "Ends"

Finally, there is the process of sterilization, preservation, and transportation of prepared foods at the "Ends". Since prepared foods are rich in nutrients, especially animal prepared foods, this makes them highly susceptible to microbiological contamination during storage and distribution [75], which is not conducive to shelf preservation of prepared foods and can greatly reduce their shelf life and affect sales. Therefore, the sterilization of prepared foods is particularly important. The sterilization, preservation, and transportation of prepared foods are closely linked in the meantime. The sterilization effect of pre-prepared products and the different methods of sterilization will determine the subsequent preservation process and the way that the products are transported. For example, prepared milk products that are only pasteurized need to be kept refrigerated at low temperatures, but those that are instantaneously sterilized at ultra-high temperatures can be stored at room temperature for a longer period. Sterilization technology is mainly divided into thermal sterilization technology and non-thermal sterilization technology. Thermal sterilization technology kills microorganisms and inactivates enzymes through thermal effects such as high temperatures. However, it is also easy to cause damage to the nutrients in the food, and thermal sterilization technology can easily cause the "overcooked taste" of meat [5]. Non-conventional food sterilization technologies can avoid these negative effects and include the use of non-thermal effects such as cavitation effect, radiation, and high pressure on the cell wall or cell membrane of microorganisms to destroy them, to achieve the purpose of sterilization [76]. There are a variety of types of new sterilization technologies, including microwave sterilization [77,78], high-pressure (HPP) sterilization, pulsed electric field (PEF) sterilization, irradiation sterilization, biological sterilization, and so on [79]. However, the main preservation methods are refrigeration, freezing and modified atmosphere, and so on. For example, most of the aquatic prepared foods are preserved by refrigeration and freezing, while the fruit and vegetable prepared foods are mainly preserved in a modified atmosphere.

5.4. Outlook on the Processing of Prepared Foods

In summary, the processing of prepared foods has generally entered the era of mechanization, and most of this processing is carried out by using mechanical equipment to replace the traditional manual-based processing mode. Various technologies and equipment have been well upgraded [80]. For example, new developments include the equipment of fruit and vegetable washing and sorting lines [81], air fryers, steamers, baking ovens, smart woks, and the technologies of ultra-high-pressure sterilization, irradiation sterilization, bio-sterilization, and cold chain transportation [82]. However, at the same time, there are also some shortcomings. Compared to other countries where prepared foods are well developed, the degree of intelligence, standardization, unification, and systematization of the

prepared foods' processing line is low, the efficiency of processing equipment is low, and the production of many prepared foods is still mainly operated by manual labour. To meet the requirements of standardization, unification, and systematization of prepared foods, enterprises mostly adopt the mode of the central kitchen in the production of prepared foods, which is the current trend of high intensity, intensification, repetition, and standardization in the catering industry. As a processing place for finished and semi-finished dishes, the central kitchen is currently partially automated in the raw material pre-processing of prepared foods [83]. However, the current processing equipment for prepared foods is still far from meeting the rapid development of the industry, and intelligent machining is considered the direction of development. Among them, the intelligent identification and classification of food ingredients is the key to achieving the intelligent pre-processing of food ingredients in the central kitchen [84]. A more vivid expression of the processing technology of prepared foods is shown in Figure 4.

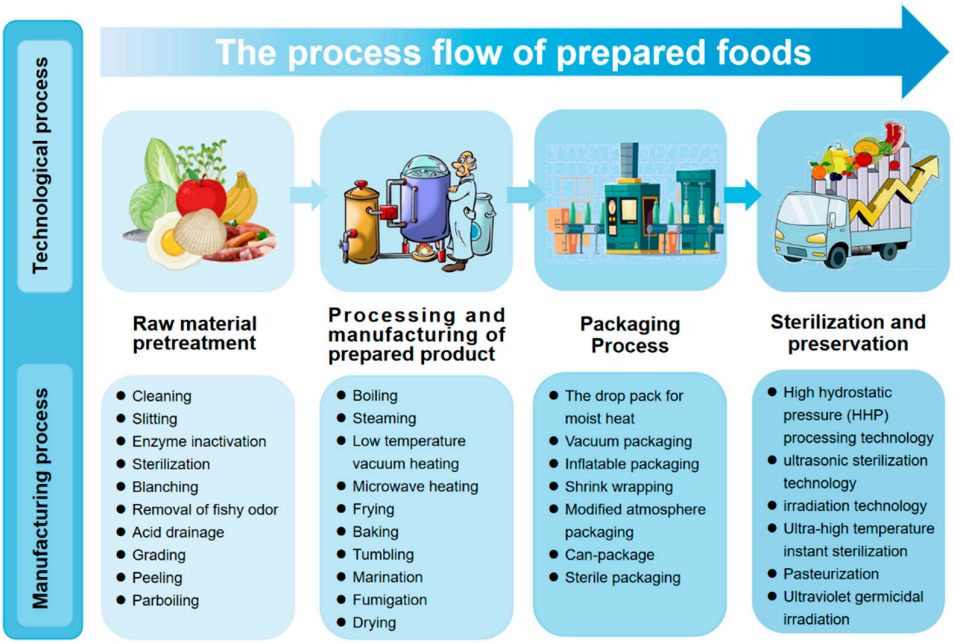

Figure 4. The processing of prepared foods.

6. Sterilization and Packaging of Prepared Foods

Prepared foods' sterilization and packaging preservation technology is, to some extent, a prerequisite factor for the development of prepared foods and has played a major role in promoting the vigorous development of prepared foods in terms of technology [76].

6.1. Sterilization Technology

Sterilization is the most important method to keep prepared foods from being contaminated by microorganisms that can spoil them [85]. Thermal sterilization is currently the most widely used method in the prepared foods industry because it is stable, effective, and low-cost. Traditional thermal sterilization technology is mainly through high-temperature heating to achieve sterilization (commercial sterilization) [86], which can kill most of the microorganisms and spores in prepared foods, greatly extending the shelf life of prepared foods, and methods include pasteurization [87] and ultra-high-temperature instant sterilization. However, the limitation of traditional thermal sterilization technology is that it will destroy the nutritional value of prepared foods and change the sensory quality of prepared foods [88]. Companies or laboratories in the industry are currently developing non-traditional food sterilized technologies in order to overcome the limitations of thermal sterilization technology [76]. Non-conventional food sterilization technologies can be divided into two main categories: the first refers to the use of high-pressure treatment, UV,

pulsed light, ultrasound, and pulsed electric field combined with heat treatment; the other category is purely non-thermal technology, including cold plasma technology [89] and irradiation technology [76]. This review focuses on high hydrostatic pressure (HHP) processing technology, ultrasonic sterilization technology [90], and irradiation technology [91].

High hydrostatic pressure processing technology is a new type of non-thermal food processing technology [92]. Prepared foods placed in specific containers will be subjected to extremely high pressures (usually over 600 MPa), and this pressure is then transmitted to the microorganisms through the medium (usually water), which induces damage to the cell membrane, leading to denaturation of cellular proteins and a decrease in intracellular pH, resulting in microbial inactivation. HHP is able to inactivate most of the bacterial microorganisms [93] in prepared foods without causing changes in the sensory and nutritional value of the foods [94].

Ultrasonic sterilization technology [95] is used to inactivate microorganisms through the cavitation phenomenon generated by ultrasonic waves [96]. Ultrasound is a pressure wave with a frequency equal to 20 kHz or higher. Ultrasound will cause bubbles to form in the liquid medium, and then the liquid bubbles will continue to grow until the energy of ultrasound is not enough to support the gas phase in the bubbles, which will cause the bubbles to collapse rapidly and produce a shock wave. The shock wave will produce extremely high temperature and pressure in the local area in a short time (less than 100 ns), and the high temperature and pressure will kill microorganisms and achieve the purpose of sterilization. Ultrasonic sterilization is usually combined with thermal sterilization to achieve the best sterilization results [97]. Ultrasound can accelerate the thermal sterilization of prepared foods and reduce processing time and nutritional loss, and its ultrasonic frequency for sterilization is generally 20 to 100 kHz [77].

Prepared food irradiation [98] is a non-thermal process that achieves microbial inactivation by exposing the food to a certain amount of ionizing radiation generated artificially or by natural sources [99]. The lethal effects of radiation on microorganisms are classified as direct or indirect. The direct effect is that the radiation damages the DNA of the target microorganism, inhibiting DNA synthesis to prevent cell division; the indirect effect is due to irradiation interacting with water molecules, leading to the production of reactive molecules, the production of which eventually leads to microbial cleavage. There are three main food irradiation technologies, namely, electron beam, X-ray, and gamma rays. Electron beams and X-rays are produced by mechanical sources and can be turned on and off, while gamma rays are produced by radionuclides and are somewhat dangerous [100]. Irradiation technology is a non-thermal process, which has a short processing time, is environmentally friendly, and does not produce chemicals and residues [93]. However, nutritional changes may result. The effects of cooking followed by irradiation (10 kGy) on vitamins B1 and C, and the antinutritional factors, phytic acid and nitrates, in a ready-to-eat meal of sorghum porridge and spinach-based relish, were investigated [101].

Although the above sterilization technology has made long-term progress compared to thermal sterilization technology, there are still certain limitations. For example, high hydrostatic pressure processing technology is only suitable for fluid prepared foods that can be packed into specific flexible bags, ultrasonic sterilization technology is not effective for dry prepared foods, and irradiation technology is more costly and has high requirements for the surrounding processing environment. Furthermore, although many efficient and high-quality sterilization technologies are being developed, compared to other developed countries, the application of advanced and efficient sterilization technologies in China are still in the early stage, and new sterilization technologies have not been widely used in the processing of the prepared foods industry. Thus, the sterilization technology of pre-prepared foods needs to be further developed to combine different sterilized technologies to achieve true sterilization that is highly efficient and of high quality. At the same time, it is necessary to strengthen the industrial application of advanced sterilization technology and promote new sterilization technology to benefit the food industry [86]. More sterilization techniques are summarized in Table 2.

Table 2. Sterilization technology for prepared foods.

Sterilization Technology	Technology Introduction	Application Products	References
Conventional thermal sterilization	Conventional thermal sterilization is mainly through different ways to produce the thermal effect of the destruction of macromolecules and other substances in microorganisms, resulting in the inactivation of microorganisms to achieve the purpose of sterilization, and mainly includes steam autoclaving, ultra-high-temperature instantaneous sterilization, pasteurization, and so on.	Cereals, seeds, nuts, and jerky.	[102,103]
Radio frequency sterilization	The sterilization mechanism of radio frequency sterilization is similar to microwave sterilization in that there is both a thermal and a non-thermal effect. The thermal effect is mainly to generate heat in the sterilization matrix to kill microorganisms, while the non-thermal effect is mainly to kill microorganisms by disrupting their protein synthesis, damaging DNA, and destroying membrane integrity.	Dried strawberries, apple juice, mashed potato, and sauces for instant food (LHHVS).	[104,105]
Microwave sterilization	Microwave sterilization is a highly efficient and energy-saving sterilization technology with a good sterilization effect and a small impact on product quality but, at the same time, it has the disadvantage of thermal inhomogeneity. Therefore, it is mostly used in conjunction with ultrasonic, pasteurization, and other technologies to achieve better results.	Pre-packaged carrots, mango puree, vegetable smoothie, and egg white.	[106–108]
Irradiation sterilization	Irradiation sterilization is a non-thermal sterilization technology that kills microorganisms on the surface of food or packaging materials through a dose of ionizing radiation emitted from an artificial irradiation source, and mainly includes gamma rays, X-rays, and electron beams.	Dry foods, frozen foods, and food packaging materials.	[109,110]
Sonodynamic sterilization technology	Sonodynamic sterilization technology is a new non-thermal sterilization technology, which, combined with sonosensitizers, can achieve efficient, safe, residue-free sterilization of microorganisms in food while effectively avoiding the induction of bacterial resistance, and it does not affect the quality of food.	Not available	[111,112]
High hydrostatic pressure processing technology	High hydrostatic pressure processing is a non-thermal sterilization technology that kills microorganisms by damaging their macromolecules through high hydrostatic pressure, such as the structure of proteins and DNA molecules. It can ensure the maximum degree of food safety and quality based on the sterilization of food.	Retort rice products, cooked hams, and sausages.	[113,114]
Cold plasma technology	Atmospheric cold plasma technology is a promising non-thermal technology for controlling spoilage of food products and for sterilizing food packaging materials. It can be economically efficient while minimizing the impact of sterilization on food quality.	Canned products and retortable pouches.	[115,116]
Pulsed electric field technology	Pulsed electric field technology is an alternative sterilization method for the thermal pasteurization of liquid food. It has a short action time, mild action conditions, good sterilization effect, and can reduce the contaminating microorganisms in food without affecting its quality.	Filled juice drinks, germicidal milk, and bottled wine.	[117,118]
Ohmic heating technology	Ohmic heating technology is a new type of sterilization technology applied to the food sector. The technical principle is to apply direct current directly to the food, which causes heat to be generated inside the food due to the natural electrical resistance of the food, thus killing microorganisms. It has the characteristics of short heating time, uniform heating, and high microbial inactivation rate.	Fermented red pepper paste, mango pulp, Korean turbid rice wine, and makgeolli.	[119–121]

6.2. Packaging and Storage Technology

The packaging of prepared foods is critical to the preservation, transportation, and distribution of the product [122]. The choice of packaging for prepared foods needs to be adapted to the properties of the product itself, and different types of packaging need to be selected according to the type of raw materials and processing, preservation, and transportation conditions of prepared foods, so as to maintain the quality of the product [123]. Currently, the most widely used packaging materials on the market are plastic bags, cling film, and glass jars. For instance, dried small fish and other dry prepared foods are mostly packaged using plastic packaging bags; vegetables are mostly packed with cling film plus composite material packing boxes; glass jars are mostly used for canned yellow peaches, chilli sauce, and another ready-to-eat pre-prepared food packaging. However, new food packaging materials are suitable for minimally processed, easily prepared, and ready-to-eat "fresh" food products, as well as matching packaging technology, and they are still in urgent need of research and development, in order to meet the industry's high demand for prepared food packaging materials [122].

Intelligent food packaging [124] is considered a future development trend which is a new and efficient way to economize on business processes, solve safety and quality issues through the supply chain, and reduce product losses. Intelligent packaging technology can make certain adjustments to parameters such as humidity, temperature, and gas microenvironment based on changes in the environment in which the prepared food is located and takes the initiative to make targeted adjustments to product quality [125]. These packaging technologies could play a role in extending the shelf life of foods and reducing the risk of pathogens. If antimicrobial agents are added as a functional component to a starch foam substrate to prepare biodegradable packaging materials, the functional foam in the packaging material exhibits a behaviour of controlled oxygen release with a longer oxygen release period and lower initial release rate when in humid conditions. The active antimicrobial substance is encapsulated and placed in the food antimicrobial packaging film with intelligent controlled release performance [126], so it can release the antimicrobial substance according to the change of environmental pH, which has good preservation and a preservative ability for products such as soup and pork, and effectively extends the shelf life of the products [127]. Research has also shown that a significant shelf-life prolongation was obtained with 30% CO_2 in the package, corresponding to a 168% shelf-life increase compared to the control sample in the air. In addition, with the introduction of national environmental protection policies and social awareness of environmental protection [128], the degradability of prefabricated food packaging materials also has higher requirements. As a relatively green, safe, and non-polluting packaging material [129], biodegradable food packaging material has great potential in the field of pre-made food packaging. We apply the knowledge of physics, chemistry, and biology to improve the development of existing biodegradable materials to reduce the negative impact of materials on the environment while enhancing the functionality and adaptability of prepared food packaging materials and promoting the development of prepared food packaging in an environmentally friendly and sustainable direction [130]. However, although food packaging technology such as intelligent food packaging has many advantages, compared to some countries with more developed food industries, the research on advanced packaging technology in China is not in-depth, and the scope of application is also limited given the high cost.

Preservation of prepared foods is crucial to the sensory quality and sale of prepared foods. Currently, drying, refrigeration, and chemical preservation are the most important methods to preserve prepared foods [63]. Refrigeration is currently the most widely used preservation technology in the prepared foods industry. Refrigeration can be divided into freezing and refrigeration depending on the temperature at which it is kept, and frozen prepared food is kept below 0 °C, generally −18 °C. The storage temperature of refrigerated prepared foods is usually 0 to 5 °C. Refrigeration can effectively extend the shelf life of prepared foods and requires low cost and easy operation of the equipment. However, freezing can significantly affect the sensory quality and nutritional value of prepared foods,

and the freezing process of water condensation into ice crystals can lead to volume expansion, water migration induced by osmotic pressure gradients, and solute concentration changes in prepared foods, which can cause irreversible textural damage to prepared foods. This leads to protein denaturation, which is detrimental to the effective long-term preservation of prepared foods. Thus, new preservation techniques are urgently needed. The hurdle is a new concept of safe, stable, nutritious, tasty, and economic preservation of food products [131], which allows stable and safe preservation of prepared foods even without refrigeration through a combination of different preservation factors or techniques ("barriers"), where the main preservation factors are temperature, pH, electrochemical potentials, and competitive flora [132]. This technology allows for multi-targeted, gentle, and reliable preservation to avoid damage to food [133].

7. Existing Deficiencies in the Development of Prepared Foods

7.1. Food Safety

As an important part of social public safety, food safety is related to the life and health of the whole nation [134]. On 6 May 2022, the website of the Chinese General Administration of Market Supervision released a circular on the supervision and sampling of food safety in China's market supervision departments in 2021. The circular showed that the national market supervision and sampling failure rate in 2021 was 2.69%, up 0.38 percentage points from 2020. Among them, the fourth quarter supervision and sampling failure rate was 2.85%. From the sampled food varieties, the sampling failure rates of processed food products of edible oils, fats, meat products, egg products, and dairy products were 0.84%, 1.35%, 1.26%, 0.24%, and 0.13%, respectively, which were all lower than the overall sampling failure rate.

Compared to the previous year, the food sampling failure rates of tea and related products, bee products, and the other 21 categories had reduced, but the sampling failure rate of beverages, food, and agricultural products had increased. From the detected categories of unqualified items, some unqualified items accounted for the total number of unqualified samples as follows: excessive pesticide residues, 26.38%; microbial contamination, 22.40%; the use of food additives in excess of the scope and limits, 12.24%; veterinary drug residues exceeding standards, 10.10% [31]; heavy metals and other pollution, 8.36%; and organic pollution problems, 8.30% [135]. Among them, agricultural products and meat products are the main source of raw materials for prepared foods, while pathogenic microorganisms, toxic animals, and plants entering the food supply and chemical contamination are the major sources of risk for prepared foods' safety [136]. Therefore, the raw material safety control of prepared foods is particularly important [137], and raw material quality control as well as a traceability system is needed to ensure the reliability, safety, and traceability of raw material sources [138].

The processing of prepared foods is also a high point for generating food safety problems [139]. The processing may produce harmful substances. For example, nitrites, proteins, and sugars may produce acrylamide in the high-temperature processing; they are mainly produced in the fermented meat curing process. These substances can be harmful to humans [140] and create food safety problems, so they need to be reduced in content, avoided, or removed through certain processes [141]. Heat treatment is the main means of controlling spoilage and pathogenic bacteria during the production and processing of prepared foods. Advantages of thermal processing include the inactivation of food-borne pathogens, natural toxins, or other detrimental constituents, prolongation of shelf life, improved digestibility and bioavailability of nutrients, and improved palatability, taste, texture, and flavour [142]. Some prepared foods are not usually sterilized after processing or are only pasteurized and are then refrigerated to maintain the flavour, nutrition, and sensory quality of the product as much as possible. However, low-intensity heat sterilization techniques such as pasteurization cannot effectively kill the bacilli of some pathogenic bacteria, such as *Bacillus thermophilus*, *Bacillus cereus*, *Bacillus aerogenes*, and *Bacillus botulinum*. As a result, when the conditions are suitable, the bacilli will regrow

into pathogenic bacteria, thus also causing foodborne illnesses and other safety problems. For example, Nout et al. found that major risk-enhancing factors of fermented foods are the use of contaminated raw materials, the lack of pasteurization, and the use of poorly controlled natural fermentation [143]. Therefore, the control of each environmental variable and component composition during the processing of prepared foods and the assessment of the sterilization method and degree of sterilization of prepared foods are extremely important and play a massive role in the food safety assurance of prepared foods.

Finally, prepared foods may be contaminated and spoiled during transportation due to unavoidable factors [144]. Prepared foods for refrigerated distribution [145] must be transported and preserved at low temperatures to prevent or delay food safety problems caused by microbial growth [146]. The Sanitary Code for Food Cold Chain Logistics stipulates that the preservation temperature during the transportation and circulation of refrigerated food should not be higher than 10 °C. Therefore, temperature fluctuations during the preservation and transportation of prepared foods is an important hidden danger for food safety [147]. Some studies have shown that the temperature of cold chain trucks can rise above 10 °C during the summer months when loading or unloading net vegetables [148]. Prepared foods purchased by many consumers will have varying degrees of warming due to the lack of means of refrigeration. If salmon and meat products purchased are without any refrigeration measures in the process of being transported to consumers' homes, the temperature of the products will rise to 13 °C and 9.8 °C, respectively, within 40 to 75 min. In addition to temperature fluctuations, contamination by cold-loving pathogenic microorganisms can pose a threat to the safety of pre-prepared foods. For example, *Listeria monocytogenes* [149] can survive and grow in anaerobic and aerobic conditions from −1.5 to 45.0 °C [150]. It can cause diseases such as invasive listeriosis, gastroenteritis, and liver inflammation [151]. In addition, ready-to-prepare foods may also cause food safety problems due to insufficient heating time and temperature for consumers. All these possible food safety triggers need to be considered within the scope of product quality control.

The development trend of food safety in the future is predicted in many directions. Among them, artificial intelligence (AI) technologies are supposed to be a powerful solution used to improve food yield, quality, and nutrition, increase safety and traceability while reducing resource consumption, and eliminate food waste. AI and big data, as the fourth industrial revolution, through its powerful data, algorithms, and computing power, could have a huge impact on the safety of prepared foods [152].

7.2. Loss of Nutrition and Flavour of Prepared Foods

The taste, flavour, colour, and nutrition of prepared foods are key factors in determining whether consumers buy them. However, prepared foods are not easy to preserve [153], and most of them require cold-chain transportation to each sales location. In the process of processing, preservation, distribution, and consumption, prepared foods need to go through the process of bumping, kneading, chilling/freezing, and then thawing and reheating [154]. After these processes, their sensory qualities, such as colour, flavour, taste, and appearance, will be affected [62]. For example, the colour becomes dull from bright, the aroma becomes dull from wealthy, the original flavour disappears, the taste becomes disgusting from palatable, and the appearance becomes shrivelled and collapsed from full and tender. All of these are possible sensory quality problems [155]. Currently, the maintenance of sensory quality is a major challenge for the prepared foods industry, which needs to ensure that the sensory quality of prepared foods is not compromised, while at the same time taking into account the elevated costs. The balance and technical requirements still need to be studied and solved [156].

Sugars, fats, proteins, vitamins, dietary fibre, and other nutrients [157] are all needed by the human body. They may change during product processing, preservation, and transportation, resulting in their deterioration or loss. For example, Pongpichaiudom et al. found that frying, microwave drying, infrared drying, and hot-air drying can affect

the microstructure and quality of protein-enriched instant noodles [158]. At present, the possible changes of nutrients in prepared foods during processing, preservation, and transportation are not concluded and still need to be researched continuously. However, processing methods such as water washing, high-temperature cooking, heat sterilization, and frozen storage cause the loss of vitamins and minerals in prepared foods [33]. In addition, some special prepared foods [159] contain a variety of flavonoids, polyphenols, functional lipids, and other bioactive substances, such as artichokes, "DiFara", deep-sea fish oil, and pre-prepared sea cucumber soup. It provides the pre-prepared foods with some beneficial physiological functions, such as anti-aging, anti-fatigue, sleep aid, and improvement of human immunity [160]. The changing patterns of these active substances during the processing, preservation, and transportation of the products are yet to be explored [161]. How to retain the bioactive ingredients in prepared foods as much as possible and maintain the nutritional quality of prepared foods are the key to broadening the prepared foods market and promoting the development of prepared foods towards high quality.

At present, there are many ways to reduce the loss of nutrition and flavour of prepared foods. For example, the flavour and nutrient content of prepared foods of fruits and vegetables can be maintained by selecting the best-tasting genotypes to produce, using an integrated crop management system and harvesting at the maturity or ripeness stage to optimize eating quality at the time of consumption, and by using the post-harvest handling procedures that will maintain optimal flavour and nutritional quality of fruits and vegetables between harvest and consumption [162]. Other ways to reduce the loss of nutrition and flavour of prepared foods include using more advanced packaging, such as active packaging, including modified atmospheric, antimicrobial, antioxidant, intelligent packaging, and nanotechnology in food packaging, and using preservation techniques such as ultra-low temperature freezing [163]. Although there are many ways to reduce the loss of nutrition and flavour of prepared foods, their application and optimization still need more research.

7.3. Intelligent Processing Equipment

Prepared foods' processing methods such as raw material pretreatment, conditioning, and high-temperature cooking technologies are particularly important for the maintenance of the sensory and nutritional quality of prepared foods, control of processing costs, and improvement of processing speed and efficiency. First, the source of raw materials for prepared foods is often the most primary agricultural products, which may have some problems. For example, agricultural products often have different shapes and sizes of raw materials. When selected and processed manually, there are some problems of low efficiency, high cost, and inconsistent subjective human judgment [84]. Due to the inconsistent quantity and quality of raw materials of primary agricultural products, it is impossible to standardize the products like industrial parts by using ordinary processing equipment. In particular, the processes of peeling, cutting, and selecting at the front end of agricultural products require equipment with calculation, debugging, and adaptation functions [164]. In addition, the conditioning and thermal processing of prepared foods requires intelligent processing equipment for production and control. Prepared foods require well-organized supply chain logistics, advanced processing equipment, and technologies [165]. For example, they are required to be marinated, kneaded, and frozen after the ingredients have been prepped. Manual control of the process of curing, kneading, freezing, and other parameters will have human subjective differences, resulting in the same prepared food in different central kitchen production locations having different sensory quality and nutritional quality levels, which will have a huge impact on the sales of prepared foods. Thermal processing also has the same problem. When the raw materials of prepared foods are pre-processed and seasoned, they need to be cooked by thermal processing, such as deep-frying, steaming, and microwave heating. The temperature and time of frying, the fire and time of steaming [166], and the time of microwave heating can lead to an inconsistent sensory

and nutritional quality of the same prepared food produced in different central kitchens due to different subjective judgments of people. Thus, a piece of intelligent processing equipment that can calculate, debug, and adapt is urgently needed; it should not only solve the problem of maintaining sensory quality and nutritional quality, but also improve the production efficiency of the industry chain, reduce labour costs, and lower production costs [167].

The central kitchen, as a place for processing finished and semi-finished products of prepared foods, has achieved partial automation in the process of raw material pre-treatment and hot cooking. However, to achieve the best efficiency of food processing, it also needs to upgrade the central kitchen equipment brought by intelligent processing equipment [168]. Ramirez-Asis et al. think that intelligent machining refers to food-wise processing equipment with perception, analysis, learning, reasoning, decision-making, and control functions [169], which is the integration and deep fusion of advanced processing technology, information technology, and intelligent technology [170]. The functions of intelligent processing equipment include intelligent identification and classification of food materials, intelligent identification and cleaning of food materials to divide, and intelligent calculation and identification control of the whole process. Using intelligent machining equipment for processing can improve processing efficiency and reduce costs [171]. For example, the intelligent machining of fruits and vegetables, fish, and meat not only reduces the volume of the equipment but also provides a device that can clean and cut a variety of food materials. Compared to traditional automated processing equipment, its processing efficiency has increased, and the cost of processing is lower [172]. In addition, through combination with artificial intelligence technologies [173] such as high spectral combination neural network intelligent technology, relying on hyperspectral technology multi-sensor acquisition of food processing images [174], and in cooperation with the neural network control module, intelligent processing equipment can achieve self-adaptive, self-control of the food processing process. It truly achieves unmanned, automated. and intelligent pre-prepared food processing and promotes the disruptive development of the pre-prepared foods industry [167].

7.4. Related Standards of the Prepared Foods Industry

Prepared food encompasses many types, so it is also subject to national and industry standards for the relevant food categories. The basic property of prepared food is pre-packaged food, so it must comply with the national food safety standards for pre-packaged food related to the provisions of the general standards. According to the types of raw materials, cooking methods, and processing methods, prepared foods can also be divided into different categories. For example, meat prepared foods need to comply with national standards for meat and meat products, and frozen prepared foods need to comply with national standards for frozen products and other relevant standards [175].

The current proprietary standards on prepared foods are mainly some local standards and group standards in China, largely for the concept of prepared foods, classification, processing technology, cold chain transportation, and other preliminary provisions, which will play a positive role in the development of the prepared foods industry. For instance, there are local standards about terms, processing specifications, and definitions for prepared foods in DB4501/T 1-2022, T/LYFIA 034-2022, and T/CCA 024-2022, respectively (this is the standard number in China). However, with the continuous expansion of the prepared foods market, the lack of national standards for prepared foods has become a key issue which restricts the further healthy development of the prepared foods industry [176]. In particular, there are many concerns about the use of a variety of raw materials. A variety of processing methods should be used to produce specific product standards in the actual production process of enterprises. The current prepared foods industry involves food processing, animal husbandry, catering, retail, and many other fields. The national standard system in terms of hygiene testing, raw material processing, and packaging and transportation methods still needs to be further improved to guide the development of

the industry [177]. For example, there is no clear standard on CFU and E. coli number of different types of aquatic prepared products (storage time is different), which may pose a threat to public food health safety. In addition, pre-prepared food safety standards, raw material standards, processing technology protocols, and product standards (including physical and chemical indicators, sensory quality, and microbiological indicators) also need to accelerate the progress of the establishment. For example, there is only a general hygiene code for food production but no specific hygiene code for prepared food production. However, that is needed, because the processing of prepared foods is often more prone to problems that threaten food safety. Relevant cases can be referred to the US Food and Drug Administration's expedited approval programs, which allow for a customized approval approach that enables market authorization on the basis of less rigorous evidence in exchange for requiring post-market evidence generation [178]. In this way, the rapid development and implementation of prepared food standards can be achieved in the hope of solving the current difficulties of the prepared food industry.

At the same time, referring to the food safety supervision system based on a hierarchical multi-domain blockchain network proposed by Qi et al. [179], we have also proposed the blockchain autonomous standard-setting model. Combining the characteristics of blockchain, such as distribution, transparency, and collegiality, with the actual needs of regional autonomy, we propose the regional standard self-submission mechanism and the secondary-check mechanism. The model realizes the accurate and rapid production of food industry standards through the free submission of food standards in sub-regions, sub-node review, evaluation (the system comprehensively evaluates the various situations of the standard subverters in the prepared food industry and the market feasibility of the standard), and regional trial. After the trial, a secondary check will be carried out to consider whether to promote the whole region. This model can provide fast service for the formulation and operation of industry standards efficiently and independently.

8. Conclusions and Prospects

The current market environment and the market demand have driven the emergence of prepared foods in China. Furthermore, from the current development status of prepared foods, its future market prospects are good, but at the same time, the development of prepared foods also has some shortcomings. Possible food safety problems during the processing and transportation of prepared foods are still poorly controlled. The phenomenon of nutrition and flavour loss during the processing, transportation, and preservation of prepared foods is poorly controlled. Moreover, prepared foods are still in the early stage of development in China, due to the variety of Chinese prepared food types and cooking methods, as well as consumers' needs for taste reduction, safety, and nutritional properties of prepared foods. There is an urgent need for more advanced processing technologies and equipment for raw material pretreatment, conditioning, thermal processing, sterilization, and preservation of prepared foods. However, the traditional prepared foods' manufacturing processes and methods have not been suitable for the needs of the new food industry. Consequently, to strengthen the research and provide more input on prepared foods, promoting the unification, intensification, standardization, automation, and intelligence of the whole production line process equipment is extremely necessary. That will no doubt result in less cost and more market shares. The standards and regulations on prepared foods are also seriously inadequate, which will lead to a difficulty for companies to reasonably control the indicators of their parameters during the processing and preservation of prepared foods, thus creating possible food safety risks. Relevant departments need to further build a complete standard system for prepared foods, which in a narrow sense means building a quality management mechanism for prepared foods, including Good Manufacturing Practice (GMP) for product traceability, quality certification, quality monitoring, and quality control. Broad standards are based on the prepared foods industry chain, where the chain is from raw material supply to production and processing to storage and circulation, from production hardware construction to information management, and

from full flow traceability to random monitoring and testing. By setting standards to regulate behaviour, the production process of prepared foods is orderly and efficient, and the terminal is safe and controllable. The blockchain autonomous standard-setting model that we have proposed can then help solve these problems.

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