Technology and Microbiology of Chinese Fermented Vegetables

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Edited by

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PREFACE

Fermented vegetables are made from fresh vegetables and are primarily fermented by beneficial microorganisms, mainly lactic acid bacteria (LAB). With a long history and profound cultural heritage, these vegetables are often used as side dishes or cooking condiments and are beloved by consumers worldwide.

Due to differences in production processes, regional environments, and food culture, fermented vegetables in China have developed a wide variety of local specialty products such as Sichuan Paocai, Fuling Zhacai, Northeast Suancai, Yanbian Spicy Cabbage, Yibin Yacai, and Northwestern Jiangshui. Among them, Sichuan Paocai stands as a typical representative of Chinese fermented vegetables, embodying the essence of Chinese culture through thousands of years of tradition. It has the characteristics of fragrance, crispness, tenderness, and sourness and is going global! In 2022, Sichuan Province alone hada Paocai output of 4.43 million tons, with an output value of 46.5 billion yuan, and Meishan Dongpo Paocai, known as the hometown of Chinese Paocai, accounted for half of its output value.

To promote the sustainable development of traditional industries and meet the growing market demand, the author led the Fermented Vegetable Research Team (Paocai Project Team) in focused research and development, dedicating over 40 years to the field. To promote the sustainable development of traditional industries and meet the growing market demand,

the author led the Fermented Vegetable Research Team (Paocai Project Team) to concentrate on research and development. In-depth research and collection of fermented vegetable biological samples from more than 30 provinces, autonomous regions, and municipalities directly under the Central Government in China, systematic analysis of various fermented vegetable production processes and microbial community structures, breakthroughs in the preparation technology of LAB functional microorganisms and their direct-injection bacteria, large-scale and continuous fermentation technology, high-salt to low-salt preservation technology, and improved traditional processes and facilities and equipment, etc., promoted the transformation and upgrading of Chinese fermented vegetables, mainly Sichuan Paocai, from small workshops of manual operation to large-scale, modern production and processing. Our products are exported to over 100 countries and regions, turning a small dish into a significant industry.

This book comprises 4 chapters and 13 sections, primarily introducing the production process, microbial community distribution, and quality and safety control of characteristic fermented vegetables from various parts of China. It is determined that *Lactobacillus* is the main dominant bacteria in fermented vegetables in various regions, and its excellent fermentation characteristics are the key to vegetable production and processing; it enriched the three-stage fermentation theory of fermented vegetable microorganisms and the evolution law of the dominant LAB in each stage, created the “steady-state fermentation” theory, discovered the “isomorphic and heterogeneous” phenomenon, took the lead in studying the function and

safety of fermented vegetable microorganisms, and was the first to build a fermented vegetable microbial strain resource library, and also explained the quality and safety control of fermented vegetables.

This book combines theory and practice and was jointly compiled by experts from Sichuan Food Fermentation Industry Research and Design Institute Co., Ltd. and Sichuan Dongpo Chinese Paocai Industrial Technology Research Institute who have been engaged in Paocai-fermented vegetable research for a long time. The language strives to be concise, and the content strives to be scientific and practical, which can be used as a reference for fermented vegetable production and processing enterprises or colleges and universities, and research institutes engaged in fermented vegetable research.

Other professionals and technical personnel from the Fermented Vegetable Research Team (Paocai Project Team), including Zhang Qisheng, Tang Yao, Wang Dongdong, Huang Runqiu, Li Jiayi, Fan Zhiyi, Ming Jianying, Li Heng, Deng Weiqin, Zhang Wei, Li Xiongbo, and You Jinggang contributed to the compilation of this book.

I would like to take this opportunity to express my deep gratitude to the professional technicians who participated in the compilation and the authors of the reference books, papers, and literature materials! I would like to thank the Fermented Vegetable Research Team (Paocai Project Team) and colleagues in the enterprise for their support and love for me and my team!

Although the research and application of Chinese fermented vegetables (this book does not include sauces and soy sauce fermented vegetables, etc.),

mainly Sichuan Paocai, have made breakthroughs and laid the foundation for industrial development, there are many types of fermented vegetables in China, and their processes and influencing factors are complex, so the research is only the beginning. There are still many shortcomings in this book. Please criticize and correct it!

CHAPTER 1

INTRODUCTION

GONG CHEN, QISHENG ZHANG, HENG LI,
YAO TANG, RUNQIU HUANG, XIONGBO LI,
JINGGANG YOU

Section 1 Origin of Fermented Vegetables

China has been recognized as possessing the most abundant vegetable resources globally, with historical records documenting vegetable cultivation dating back more than 3,500 years. Incomplete statistics reveal that there are more than 160 types of vegetables commonly consumed in China. Vegetables have been a crucial food resource for human survival since ancient times, with many of these being utilized in primitive eras.

Fermented vegetables utilize a bio-preservation technique that employs beneficial microorganisms and various ingredients to enhance the shelf life of the final product. This results in a diverse range of flavors and high quality at a reasonable cost. In the long process of practice, our diligent ancestors have mastered various production techniques such as salt production, koji making, and ceramic techniques as can be seen in the *Shang Shu - Yu Gong* with “Qingzhou tribute salt”, which provides excellent material foundation and prerequisites for the development of fermented

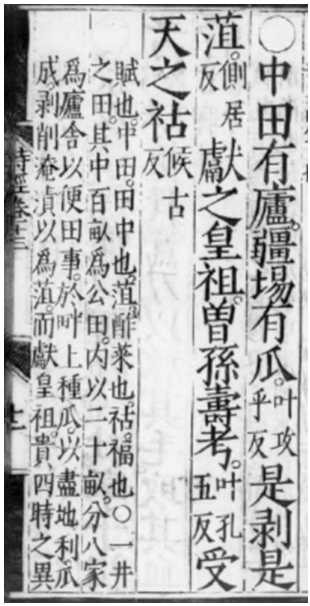
vegetables. A variety of vegetables, such as Chinese cabbage, cabbage, beetroot, radish, cucumber, celery, green tomato, pepper, green pea, and green beans, can be used to produce fermented vegetables. Furthermore, based on the market demand, fermented vegetables can be processed into various vegetable products with different flavors such as sour, sweet and sour, hot and sour, spicy, and so on.

To meet basic food needs, it's necessary to store a portion of vegetables during harvest seasons for use in leaner times. In practice, people begin preserving fresh vegetables by salting and pickling them, which is the first step in the fermentation of vegetables. Vegetables that have been treated with salt or brine are known as salt-preserved vegetables. Thus, salt-preserved vegetables serve as the precursor to fermented vegetables. Fermented vegetables, like Sichuan Paocai, represent the primary form of these traditional bio-fermented products in China. They are considered a valuable cultural heritage and have been inherited to the present day.

The Book of Songs, the earliest collection of Chinese poetry, includes a verse that goes “There is a cottage in the field, and there is a melon in the border. It is peeled and pickled, and it is offered to the emperor's ancestor.” Figure 1-1）. In this verse, the term “melon” refers to a type of vegetable, and “peeled” and “pickled”indicate the process of pickling and preservation.

According to Xu Shen’s *Shuowen Jiezi*, “Zucài” refers to pickled vegetables, which is equivalent to today’s Paocai（a kind of fermented vegetable）. Furthermore, the ancient book *Shangshu - Shuoming* records that “To make a good soup, salt and sour plum are indispensable”, which suggests that at least 3100 years ago, during the Wu Ding era of the *Shang*

Dynasty, the Chinese laboring people were already using salt to pickle vegetables and fruits. Thus, the history of salted vegetables in China predates *the Book of Songs* and is believed to have originated during the Shang and Zhou dynasties over 3100 years ago.


○中田有廬疆埸有瓜。叶攻乎反是剥是菹。側居反獻之皇祖曾孫壽考。叶孔五反受天之祜。侯古反

賦也。中田。田中也。菹。酢菜也。祜。福也。○一井之田。其中百畝爲公田。內以二十畝。分八家爲廬舍。以便田事。於叶上種瓜。以盡地利。瓜成剥削煮漬。以爲菹。而獻皇祖。貴四時之異

Figure 1-1 Zhu Xi: The Twelfth Volume of *The Collected Commentaries on The Book of Songs*

During the Western *Zhou* Dynasty (1046-771 B.C.), the Duke of Zhou authored the book *The Rites of Zhou,* which comprises six volumes: *Tian Guan*, *Di Guan*, *Chun Guan*, *Xia Guan*, *Qiu Guan*, and *Dong Guan*. The passage in "*Tian Guan*" states: "The big soup is not seasoned, one should take the soup to the small vessels and add salted vegetables before it is served." This indicates that no seasoning is added while cooking food in a large pot; salt-fermented vegetables are used for seasoning after the food is

removed from the pot. The term “salt-fermented vegetables” refers to Paocai, further verifying its historical significance.

In the early years of the Western *Han* Dynasty (202 B.C.-8 A.D.), Xin Zhui, wife of Licang, the prime minister of the *Changsha* Kingdom, was buried at *Mawangdui* in *Changsha*. After over 2000 years, the site was excavated, revealing burial relics that included salt-preserved food items such as sauce and fermented black beans, as well as salted vegetables like fermented soybean with ginger.

During the Northern *Wei* Dynasty (386-534 AD), the renowned agronomist Jia Sixie provided a relatively systematic and comprehensive account of the processing techniques for fermented vegetables before that period in his work *Qimin Yaoshu (Essential Techniques for the Welfare of the People),* which is an early written record of the standardized methods of making Paocai. The followings are some examples settled down in the book:

Salted vegetable method: “When harvesting vegetables, pick those with good quality, tie them with rushes and reeds, make saltwater extremely salty, wash the vegetables in the saltwater, and then place them in jars.” The term “jars” here refers to the action of placing the vegetables in jars or crocks. This is the method of preserving vegetables by soaking them in saltwater.

Melon pickling method: “Wash the melon, let it dry, and rub it with salt.” This is the method of pickling melons with salt.

Fern preservation method: “For every row of ferns, add a row of salt.” This refers to the method of preserving ferns, a type of wild plant, by

layering them with salt. This technique, where each layer of vegetables is covered by a layer of salt, is still in use today.

Quick pickling method: “Boil Kuicai (a type of vegetable) in vinegar broth, break it apart, add vinegar, and it becomes pickled”. This is a method for rapidly making Paocai.

The method of fermented pickling: “The rice broth should not be boiled vigorously, as excessive heat would cause the liquid to overflow. It should not be too plentiful, and the vegetables will be ready within seven days when covered with a layer of mud.” The term “mud” refers to the use of clay or soil to seal the pickling jar or container. This indicates that during that time, people already created an anaerobic environment to promote vegetable fermentation (specifically lacto-fermentation).

In *the Geographical Records of Tang Dynasty*, it is documented that *Xingyuan* prefecture offered summer garlic, winter bamboo shoots, and “Zao Gua” as tributes. The term “Zao Gua” resembles vinasse pickled vegetables in the present day such as “Zao Cucumber strips” (pickled cucumber strips).

During the *Song, Yuan*, and *Ming* dynasties, techniques for Paocai production saw significant development, with rich varieties such as soy sauce-pickled, vinegar-pickled, and sugar-fermented vegetables coming out. In the *Song* Dynasty, Meng Yuanlao, author of *Memoir of the Eastern Capital* recorded the preservation of vegetables, including “fermented spicy radish with ginger” and “freshly pickled quince.” The poet Lu You in *Song* Dynasty wrote the verse “Cabbage and mustard leaves are suitable to pickle, while celery is suitable for making soup.” The Han Yi in *Yuan* Dynasty

recorded the “Three-step BoilingMethod for Melon” in *Yi Ya's legacy*，a famous cuisine book . *Duo Neng Bi Shi* compiled by Liu Ji in the *Ming* Dynasty mentioned “pickled garlic.” In Kuang Fan’s *Bianmin Tuzuan* of the *Ming* Dynasty, there is a description of the pickling method for dried radishes (a kind of fermented vegetable): “Dice and, salt (the radish) overnight, sun-dry them, and mix them with ginger shreds, orange shreds, coriander, and fennel. Stir-fry them.”

During the *Qing* Dynasty, the variety of Paocai became remarkably rich. Detailed records can be found in works such as Yuan Mei’s *Suiyuan Shidan* and Li Huanan’s *Xingyuan Lu*. Examples of Paocai with distinct styles include Sichuan Paocai, Yibin Yacai and Nanchong Dongcai in Sichuan; Fuling Zhacai in Chongqing; Yuyao Zhacai and Xiaoshan dried radish in Zhejiang; Zhenyuan Chennian Daocai in Guizhou, and Qujing Chives in Yunnan. During the *Qing* Dynasty, Paocai was even included as part of the dowry in both southern and northern Sichuan. This tradition persists in some areas of Sichuan to this day, underscoring the longstanding importance of fermented vegetables in people’s lives (Chen,2010,1-5).

Section 2 Current Status of Industrial Development of Fermented Vegetables

2.1 Overview of Industrial Development of Fermented Vegetables in China

The craft of fermenting vegetables in China has been passed down for thousands of years, but its real development was after the founding of the People's Republic of China (PRC), especially in the 40 years of reform and opening up. With the continuous expansion of the consumer market and the

guidance of the government, as well as the efforts from the industry, academia and research, the fermented vegetables industry in China has experienced rapid development. By building upon traditional techniques and continuously improving production and processing practices, a diverse range of fermented vegetable products is available today. An increase in leading vegetable product enterprises, significant enhancement in the quality of fermented vegetable products, the emergence of well-known vegetable product brands, large-scale and standardized production and processing of fermented vegetables, the development and application of new products and technologies, the establishment of raw material bases for fermented vegetables and other factors are all specific manifestations of the innovative development of the traditional vegetable industry. China is the world's largest producer of vegetables, with production increasing year by year. Notably, Sichuan and Shandong are home to the majority of Paocai enterprises. In 2009, the market demand for Paocai in China was 26.028 billion yuan, which increased to 46.636 billion yuan in 2015. According to customs data, in 2015, China's Paocai exports amounted to 519,000 tons, a year-on-year increase of 3.26%, mainly consisting of Korean-style Paocai. The import quantity was 7,500 tons, a year-on-year increase of 33.93%. Figure 1-2 shows the number of Paocai production enterprises in each provincial administrative region of China. In 2021, the market scale of fermented vegetables in China amounted to 60 billion yuan, while the production of Sichuan Paocai in 2022 reached 4.43 million tons, with a value of 46.5 billion yuan. The products are exported to more than 100 countries and regions, accounting for over 70% of the national Paocai production.

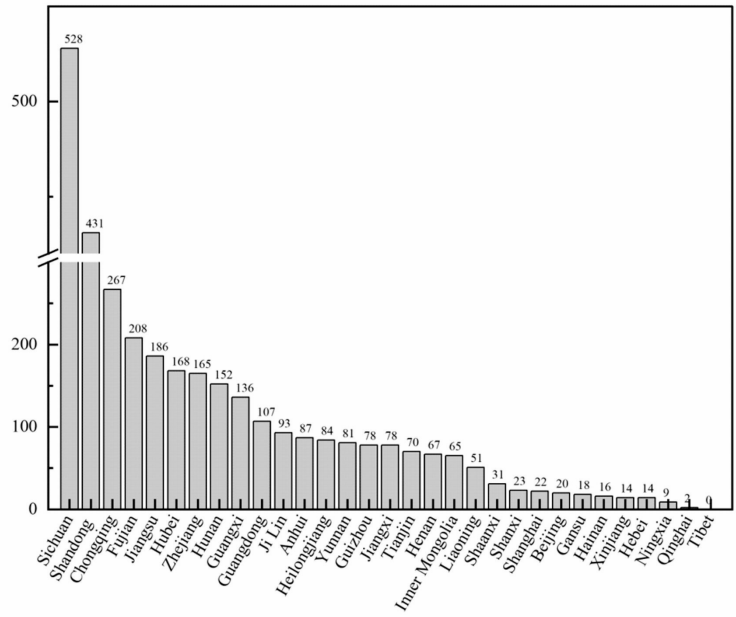


Figure 1-2 Distribution of Fermented Vegetable Enterprises in China

(Data source: National and provincial Food and Drug Administrations）

2.1.1 Sichuan Paocai

Sichuan ranks first in China for Paocai production and sales, with an annual growth rate of 10-25%. Particularly from 2000 to 2013, the annual growth rate consistently exceeded 20%. This period witnessed the emergence of nationally renowned brands such as “Jixiangju,” “Liji,” “Weijute,” “Chuannan,” “Huitong,” “Xinfan,” “Guangle,” “Yingpeng,” and “Zhou Luobo,” among others. This has led to the formation of the “Meishan-Chengdu” Paocai industry cluster, and Meishan has been honored with the title of “The Paocai town of China.” In 2008, Sichuan province had

over 170 vegetable processing enterprises with an output value of over 10 million yuan, among which there were 120 Paocai processing enterprises. The Paocai production reached 1 million tons, with an output value of 7.5 billion yuan, and processed fresh vegetables of 3.1 million tons, accounting for 10% of the total vegetable production in the province. In 2009, the Paocai production in Sichuan province reached 1.2 million tons with a value of 9 billion yuan. There were 29 provincial-level key agricultural industrialization leading enterprises and 2 national-level ones in Sichuan Paocai enterprises. There were 5 Paocai "Chinese Well-known Trademark" in the province, which have the right to export independently. By 2010, the Paocai production in Sichuan province reached 1.5 million tons with a value of 12 billion yuan. The Paocai industry in China comprises over 130 enterprises, including three national-level key agricultural industrialization leading enterprises. In 2011, the Paocai production in Sichuan province reached 1.8 million tons with a value of 15 billion yuan (including 16 enterprises that achieved sales revenues of over 100 million yuan). The processing of fresh vegetables was nearly 5 million tons throughout the year, driving the development of 100,000 hectares of raw material production base and increasing farmers' income by nearly 800 million yuan. By 2020, Sichuan province's Paocai production soared to 5.07 million tons, with an output value of 43.7 billion yuan (Figure 1-3). In 2013, Meishan, a city in Sichuan Province, exceeded the milestone of 10 billion yuan in the Paocai industry. Subsequently, the production value continued to rise, reaching 21.34 billion yuan by 2020. In 2021, Sichuan's Paocai industry had an output value of 44.6 billion yuan, in which Meishan contributed 21.9 billion

yuan. A pattern has emerged wherein “global Paocai focuses on China, Chinese Paocai focuses on Sichuan, and Sichuan Paocai focuses on Meishan.”

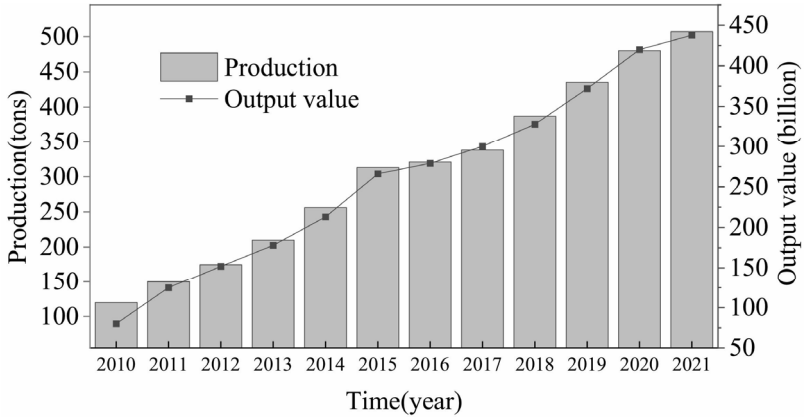


Figure 1-3 2011-2020 Sichuan Paocai Production and Output Value

In recent years, the Meishan Paocai industry has developed rapidly, and Meishan Paocai products have been exported to more than 100 countries and regions, such as the United States, Europe, Australia, Canada, Japan, South Korea,,and are highly popular among domestic and foreign consumers. Industry development presents the following significant features:

1) The Scale of the Raw Material Base Continues to Grow

The establishment of raw material bases for Paocai production and processing in Sichuan has developed rapidly, most of the leading Paocai enterprises have developed their own vegetable raw material bases, with each base covering a minimum area of 667 hectares. The supply and quality

of raw materials are guaranteed by the way of “Company + Base + Farmers”. Take Meishan as an example, in 2017, Meishan City built a standardized Paocai raw material base of 30,700 hectares, along with an organic vegetable base of 2,700 hectares. The “Paocai town of China” - Dongpo District of Meishan City has been recognized as a national modern agricultural demonstration area, China Condiment Raw Material (Brassica juncea) Planting Base and *Minjiang* Modern Agricultural Area have been designated as a national agricultural industrialization demonstration base.

2) The Development of Enterprise Clusters Continues to Upgrade

As of 2018, Sichuan Paocai has formed two Paocai industry clusters in “Meishan-Chengdu” areas, of which Meishan Paocai accounts for more than 50% of the output of Paocai in Sichuan Province. Meishan has established three Paocai industry clusters, namely China Paocai City, Songjiang Town Industrial Park, Taihe Town Economic Development Zone, with 66 Paocai enterprises, 135 standardized production lines, 3 national agricultural industrialization key leading enterprises, 8 provincial agricultural industrialization key leading enterprises, 37 enterprises classified as above designated size, 10 enterprises with over 100 million yuan, 9 enterprises obtained self - operated export rights, and 1 enterprise qualified for foreign investment. Chengdu Paocai is represented by Xinfan Paocai, which has famous Paocai brands such as “Xinfan” and “Yingbang”. After 2019, the cluster development was somewhat affected by the financial crisis and the impact of COVID-19 in 2020, which has reduced the number of Paocai SMEs.

3) Continuous Strengthening of Paocai Technology Research and Development.

The development of Sichuan Paocai industry is inseparable from the support of science and technology, and the Sichuan Provincial Party Committee and the provincial government have carried out the centralized support of science and technology projects for Paocai industry for many years (2009-2018), represented by the Science & Technology Department of Sichuan Province, “Research and Integration Demonstration of Key Technologies for High-Quality and Safe Chinese Paocai Modern Industry” (Round 1, project number 2009NZ0080) “Research, Integration, and Industrialization Demonstration of Key Technologies for High-Quality Chinese Paocai Modern Industry Chain” (Round 2, project number 2012NZ0002), and Round 3 (project number 2016NZ0007). Additionally, projects such as “Integration of Industrialized Production Technology and New Product Development for Traditional Vegetable Industry” (Project in 12th Five-Year Plan Period of China，grand number 2012BAD31B04) and “Typical Processing Deterioration and Regulation Mechanism of Salted Vegetables” (Project in the 13th Five-Year Plan Period of China)” supported by the Ministry of Science and Technology have been implemented. The Paocai technology projects conducted by the Sichuan Provincial Department of Agriculture (Sichuan Paocai Association), Sichuan Provincial Economic and Information Department, Meishan Municipal Party Committee and Government, as well as research institutes represented by Sichuan Academy of Food and Fermentation Industries, universities, and enterprises represented by *Jixiangju* Company, totaling 11

units, have been established. At the national, provincial, and municipal levels, a collaborative Paocai technology project team has been established, with the author serving as the project leader and chief expert. Through close collaboration among industry, academia, and research institutions, systematic research on Paocai has been conducted, resulting in a series of technological achievements that have been successfully applied, effectively promoting the rapid and healthy development of the Paocai industry, and solidifying its position as a prominent sector in both domestic and international industries.

Between 2009 and 2018, several Paocai research and development platforms were established, including the Paocai innovation team, Paocai research institute, Paocai engineering and technology research center, Paocai innovation alliance, and Paocai industry technology research institute. Building upon traditional microbiological methods, innovative utilization of modern molecular microbiological techniques was employed to conduct systematic studies on the microbial community structure and variations in Paocai from different regions of Sichuan. Pioneering efforts led to the identification of three genera and seventeen species of lactic acid bacteria., including strains like *Leuconostoc mesenteroides*, *Lactiplantibacillus plantarum*, *Levilactobacillus brevis*, *Lactobacillus parabuchneri*, and *Limosilactobacillus fermentum.* Subsequently, various methods such as multiplex PCR, high-throughput sequencing, and API were employed to further determine the dominant microbial population in Paocai, which consisted of five genera and eleven species of lactic acid bacteria, such as *Leuconostoc citreum*, *Pediococcus acidilactici*, *Lactiplantibacillus*

plantarum, *Weissella confusa*, and *Enterococcus*. The first domestic Paocai microbial strain resource library was established, and a "double-high" (high activity and high stability) direct-fed microbial agent was developed. Furthermore, 35 specialized vegetable varieties for Paocai production were introduced and cultivated, among which five were officially approved varieties. Over 20 key technologies for the modern Paocai industry were researched and developed, including direct-fed microbial agent preparation technology, pretreatment technology, rapid fermentation technology, color and texture preservation technology, continuous automated fermentation technology, efficient water-saving and emission reduction technology, and comprehensive utilization of by-products. Eight major categories of over 50 new products were developed, such as low-salt Paocai series, direct-fed lactic acid bacteria Paocai, assorted Paocai, clear sauce Paocai, stir-fried Paocai, snack Paocai series, and health-preserving Paocai series. Additionally, ten by-product products were created, including condiments, seasoned vegetables, and vegetable soy sauce. Key equipment such as Paocai production control units, quantitative filling and sealing systems, and continuous fermentation systems were developed. Fifteen achievements were authenticated, and a total of 14 science and technology awards were received at various levels (including 3 first-class provincial and ministerial awards). Twenty-five national, industry, and enterprise standards and technical specifications were drafted. One hundred and twenty patent applications were filed, including 52 granted invention patents and one international patent. Over 100 papers were published in domestic and international core journals, and more than 120 doctoral, master's, and

bachelor's degree candidates were trained. Several research project results filled the domestic gaps in areas such as Paocai flavor components, biogenic amines, and Paocai health research. A modern pilot production line for Paocai was established, with a capacity of 1,000 kg per year, as well as a workshop for the preparation and fermentation of direct-fed microbial agents (obtaining SC certification), a 1,000-ton per year saltwater recycling production demonstration line, a 1,500-ton per year continuous fermentation Paocai production line using direct-fed lactic acid bacteria, and five modern standardized production demonstration lines with a total capacity of 10,000 to 20,000 tons per year (including one 10,000-ton line, two 15,000-ton lines, and two 20,000-ton lines). From 2009 to 2015, over 100 million yuan was invested in Paocai technology, primarily by leading enterprises, resulting in over 500 million yuan of direct additional sales revenue. More than 500 farmers were employed, and over 6,000 hectares of land were influenced by this project, generating comprehensive benefits of over 2.3 billion yuan, icluding 1.3 billion yuan in agricultural income. Notably, this increase in income contributed to a per capita income rise of 2,500 yuan for farmers in Dongpo District, Meishan). The project has achieved significant results.

Since 2018, the government's focused support for technological special projects has experienced reductions or cancellations. However, research and development, represented by the Sichuan Dongpo Chinese Paocai Industrial Technology Research Institute and the Sichuan Academy of Food and Fermentation Industries have not stopped. Industry, research, and academia continue their efforts, with over 300 patent applications in

various industry categories at the national level, 60 authorized invention patents, and over 100 published research papers. They have successfully isolated and preserved over 11,000 strains of Paocai microorganisms and developed over 100 series of new products, including direct-inoculation fermented Paocai. Their research achievements have received several awards, including first prizes for scientific and technological progress from provincial and municipal governments and industry-related awards. Over 20 national, provincial, and municipal key scientific and technological projects have been implemented, and several achievements have been applied in production by enterprises.

To leverage the scientific and technological resources of Sichuan and Chongqing, promote the joint construction of high-level laboratories in Sichuan and Chongqing, and enhance the ability of collaborative innovation, Chongqing Science and Technology Bureau and Science & Technology Department of Sichuan Province on May 26, 2021 decided to support the "Chongqing Key Laboratory of Chinese Paocai Science and Technology Innovation". The laboratory is jointly established by Chongqing Yu Southeast Academy of Agricultural Sciences and Sichuan Academy of Food and Fermentation Industries. The laboratory is focused on the raw materials of Zhacai and Paocai for scientific and technological innovation and variety transformation, efficient raw material production and processing technology improvement, new product development and comprehensive utilization of by-products, etc., and carry out innovative basic research, applied basic research, common and key technology research and

transformation to overcome the technical bottlenecks that hinder the development of Zhacai and Paocai industry.

4) The Brand Effect Continues to Emerge

There are 8 national key leading enterprises of agricultural industrialization in Sichuan Paocai production enterprises, which have obtained 8 “China Famous Trademarks” and 19 “Famous Trademarks”. “Dongpo Paocai” and “Xindu Paocai” with “Xinfan Paocai” as the leader have become national geographical indication protected products and national origin certification trademarks. Sichuan Paocai has been reported by CCTV, *People’s Daily* and other media, and placed on the tables of delegates at the Beijing Olympics, the National People’s Congress, the Central Economic Work Conference and the 18th Party Congress. The Paocai series products are exported to more than 100 countries and regions, such as Japan, Korea, the United States and the United Kingdom.

5) Policy Support Is Increasing

Sichuan Province, along with Meishan City and other local governments, have continuously introduced policies to support the development of the Paocai industry, focusing on the construction of raw material bases, standardized production, technology research and development, brand building, payment of taxes, land saving and other aspects of support and incentives, including Meishan (2010-2018) annual financial investment of 100 million yuan to support the entire industry chain, Dongpo District annually arranged special funds of more than 20 million yuan to continuously support leading agricultural industrialized Paocai enterprises. In order to better promote the development of Sichuan Paocai

industry, under the guidance of Sichuan provincial government, Meishan municipal government held the “China Paocai Festival” (various seminars, forums, exhibitions and sales fairs, referred to as “China Paocai Expo”) for 14 consecutive years until 2024. Provincial Agriculture Department, Provincial Science and Technology Department, Provincial Department of Commerce, Provincial Department of Economic and Information and other provincial departments have given their support during this period. On July 18, 2009, the first “Sichuan Paocai International Forum” was held in Meishan City, Sichuan Province, with more than 500 participants from more than 30 countries, including notable organizations like the FAO, the United States, Japan and South Korea. The conference centered around “Japan, South Korea, China Paocai status and development trend, Sichuan Kimchi characteristics and products, history and culture, nutrition and health, Sichuan Paocai international development direction” and other content launched a high-level, high-quality discussions, attracting great attention and sparking enthusiasm for research, development, standards, branding and capacity expansion of Sichuan’s Paocai industry. This meeting was undoubtedly a milestone in the history of the development of Sichuan Paocai. Since then, the “China Paocai Expo” has been held in Meishan for 14 consecutive years, which has greatly promoted the development of the Paocai industry. At each event, the author had the honor to represent the Paocai research team and deliver speeches on Paocai technology themes.

On January 11, 2011, *the Sino-Korea Modern* Paocai *Industry Development Science and Technology Forum* was held in Chengdu, hosted by the Science & Technology Department of Sichuan Province and the