DOI 10.15302/J-SSCAE-2021.02.017

Technology Upgrading Strategy for the Traditional Fermented Food Industry in China

Xia Xiaole, Wu Jianrong, Chen Jian

School of Biotechnology, Jiangnan University, Wuxi 214122, Jiangsu, China

Abstract: With the global promotion of Industry 4.0, the technical status, challenges, and upgrading of China's traditional fermented food industry need to be clarified, and strategies and policy suggestions are required to improve the industry. Field research, questionnaire surveys, and literature analysis reveal that China's traditional fermented food industry is decentralized, intelligent manufacturing has not been properly applied to the industry, and a green manufacturing system has not yet been completed. Meanwhile, the industry faces many challenges, such as the poor capability for independent research and development of core technologies and equipment and a lack of a clear path for upgrading the industry. Therefore, key technologies should be enhanced by unearthing fermentation mechanisms and developing completely independent equipment, and standardization should be strengthened to promote end-to-end integration. To establish a novel fermented food industry, China should strengthen the top-level design and strategic guidance, promote breakthroughs in key theoretical and technological foundations, nurture a new model of shared manufacturing, encourage policies and support measures, and improve industry standards and ecosystems.

Keywords: traditional fermented food; green manufacturing; intelligent manufacturing; transformation and upgrading

1 Introduction

According to a traditional Chinese saying, seven things start every day: "firewood, rice, oil, salt, sauce, vinegar, and tea." Traditional fermented foods are closely related to people's daily lives, and they are a civilian industry with distinct Chinese cultural features. In 2018, the total value of China's traditional fermented food industry output exceeded 1.5 trillion CNY, accounting for approximately 11% of the food industry and 1.6% of the total gross domestic product. The traditional fermented food industry is an important part of China's light manufacturing industry, mainly liquor, such as Chinese Baijiu and rice wine, and condiments such as soy sauce, seasoning wine, and vinegar [1–3]. The traditional fermented food industry has been widely loved because of its craftsmanship, unique flavors, rich national features, and sustained and stable development. This industry accounts for a high proportion of the national economy with a large social impact and has increasingly become a cultural icon in China's light industry, attracting attention from the international community. Compared with the advanced international fermented food industry, China's traditional fermented food industry still mainly uses multi-strain mixed solid-state fermentation and manual or semi-mechanized operations, leading to low production efficiency and high energy consumption, in addition to problems such as unstable product quality and high environmental impact. At the same time, China's traditional fermented food enterprises have relatively low overall research and

Received date: May 14, 2020**; Revised date:** December 09, 2020

Corresponding author: Chen Jian, professor of School of Biotechnology of Jiangnan University, member of Chinese Academy of Engineering. Major research field is fermentation engineering and food biotechnology; E-mail: jchen@jiangnan.edu.cn

Funding program: CAE Advisory Project "Research on Technology Upgrading Strategy for Traditional Fermented Food Industry in China" (2019-XY-29)

Chinese version: Strategic Study of CAE 2021, 23(2): 129–137

Cited item: Xia Xiaole et al. Technology Upgrading Strategy for Traditional Fermented Food Industry in China. *Strategic Study of CAE*, https://doi.org/10.15302/J-SSCAE-2021.02.017

development (R&D) investment, low industry concentration, few core technologies, low levels of mechanization, automation, low resource conversion rates, and weak competitiveness. Therefore, comprehensive transformation and upgrades are required to drive the sustainable and healthy development of China's traditional fermented food industry.

In the China Manufacturing 2025 action plan, the basic policy of "innovation-driven, talent-oriented, quality first, green development, and structural optimization" was proposed, while "intelligent manufacturing engineering" and "green manufacturing engineering" were set as the key implementation directions. Moreover, the *Intelligent Manufacturing Development Plan (2016–2020)* issued by China's Ministry of Industry and Information Technology and its Ministry of Finance, mandates the accelerated upgrading of smart and green manufacturing in the light food industries and implements an in-depth application of smart and green technologies throughout enterprise R&D, design, manufacturing, logistics and warehousing, operation management, and post-sales service. This study focuses on upgrading intelligent and green manufacturing and studies the technical status, development trends, and problems China's traditional fermented food industry faces. This research also offers additional transformation and upgrade suggestions to promote the healthy development of the traditional fermented food industry.

2 Current status of the traditional fermented food industry in China

There are many types of traditional Chinese fermented foods. Their raw materials mainly include fermented grains, beans, tea, milk, vegetables, and meats. Most industries are represented by two fields: liquors and condiments. The traditional production of fermented food is generally an open mixed-strain fermentation system greatly affected by the environment and rich in regional and technological features [4]. As shown in Table 1, the current major traditional fermentation industries, ranked in the top five in terms of output value, include liquor, soy sauce, rice wine and seasoning wine, vinegar, and fermented sauces. Generally, the common technological characteristics of these products comprise the metabolism of their complex fermenting microbial community, a lengthy fermentation cycle, the complex composition of metabolites, and their unique flavor.

Table 1. Revenue of China's traditional fermented food industry (×100 million CNY).

Industry	2016	2017	2018	2019	2020
Chinese Baijiu	6126.0	5654.0	5364.0	5617	5060
Rice wine	198.2	195.8	167.0	173	177
Seasoning wine	78.5	90.7	109.0	130	150
Soy sauce	760.0	836.0	920.0	1000	1100
Vinegar	65.8	78.5	94.8	104	114

2.1 Traditional brewing

Traditional Chinese brewing includes Chinese Baijiu and rice wine. Sales of Chinese Baijiu fluctuated between 550 billion and 650 billion CNY over the past five years, accounting for a relatively high proportion of traditional fermented foods (close to 70%). Although Chinese Baijiu profits have increased annually, its output value has recently decreased. The current revenue and profits of the Chinese Baijiu industry show the Matthew effect. Large single products similar to Moutai are constantly emerging, and industry concentration has increased significantly. In 2018, four Chinese Baijiu companies had revenues exceeding 10 billion CNY, including Kweichow Moutai Group, Wuliangye Group Co., Ltd., Yanghe Distillery Co., Ltd., and Luzhou Laojiao Co., Ltd., which accounted for 87% of the total profit of all listed companies. At the same time, however, the Chinese Baijiu industry's losses were greater than 10%.

In comparison, the rice wine industry has the lowest revenue among the four major traditional wines. In 2016, national rice wine sales were 19.6 billion CNY. After 2018, they dropped to approximately 17 billion CNY. The top three rice wine companies—Guyue Longshan Shaoxing Wine Co., Ltd., Kuaijishan Shaoxing Wine Co., Ltd., and Jinfeng Wine Co., Ltd.—accounted for 14% of the industry's total revenue. Moreover, outstanding companies such as Zhangjiagang Brewing Co., Ltd. have gradually emerged as strong competitors (data from the annual reports of listed companies). As shown in Table 2, based on the analysis of survey data, the proportion of R&D investment and personnel in traditional winemaking enterprises are slightly lower than other traditional fermented foods. The Chinese Baijiu industry averages 0.7%, and the rice wine industry accounts for 0.4% to 0.9%, which is much lower than

DOI 10.15302/J-SSCAE-2021.02.017

the seasoning and other food industries. Overall, the output value of the traditional winemaking industry shows a downward trend. Although the large single-product strategy is beneficial to industry leaders, its expansion also reduces the market space for small- and medium-sized enterprises (SMEs). Regarding intellectual property rights, the Chinese Baijiu industry has more patents, with fewer patents issued to the rice wine industry, while the total proportion of patents for invention does not exceed 30%. Almost no alcoholic enterprises have carried out comprehensive intellectual property design.

Table 2. R&D investment of some traditional fermented food companies in 2018.

	Company	Staff	R&D staff	R&D staff ratio (%)	Patent	Patent for invention	R&D investment (×100 million)	Proportion of R&D investment (%)
Chinese Baijiu	Moutai group	26 618	551	2.1	488	51	3.86	0.52
	Wuliangye group	26 300	2680	10.2	373	41	0.84	0.21
	Jiangsu Yanghe	15 292	393	2.6	211	53	0.33	0.14
	Luzhou Laojiao	2881	452	15.7	350	9	0.85	0.65
	Xinghuacun Fenjiu	7660	275	3.6	119	18	0.12	0.13
Soy sauce	Haitian Food	5120	362	7.1	140	57	4.93	2.89
	Meiweixian Food	4588	557	12.1	221	87	1.22	2.90
	Qianhe Food	2089	33	1.6	51	41	0.20	1.91
	Jiajia Food	1394	88	6.3	23	13	0.26	1.47
Vinegar	Hengshun group	2627	98	3.7	265	149	0.48	2.82
Rice wine	Guyue Longshan	2448	105	4.3	109	9	0.08	0.48
	Kuaijishan group	1470	76	5.2	99	34	0.12	0.97
	Shanghai Jinfeng	1096	24	2.2	50	20	0.04	0.40

2.2 Fermented condiments

The output value and profit of China's fermented condiment industry have shown an overall upward trend over the past three years. Soy sauce accounted for the largest proportion. In 2018, the output of soy sauce reached 10.4 million tons, with sales of 92 billion CNY, and the top six companies accounted for more than 23% of total soy sauce sales. Industry concentration is the highest among traditional fermented foods [5]. In contrast, industries such as vinegar, seasoning wine, and fermented sauces have relatively low concentrations. Most of them are workshop-style enterprises, and only a few leading enterprises have achieved large-scale production. The production capacity of the vinegar industry was relatively high. The revenue of Hengshun Vinegar Inc. accounts for 5.2% of the market, and the second to fourth companies account for 9.7%. In 2018, the output of the vinegar industry was close to 5 million tons, with sales of 9.48 billion CNY.

The seasoning wine industry grew rapidly, but the competition was fierce. The top five manufacturers accounted for approximately 17% of the total revenue and were mainly focused on several brands, such as Lao Henghe, Lao Caichen, Wang Zhihe, and Hengshun. Fermented sauces are primarily fermented condiments made from beans, including Pixian bean paste, soybean paste, fermented bean curd, and tempeh. The annual output of fermented sauces was maintained at approximately 750 thousand tons. Haitian food relied on its technology and brand advantages, and its soybean sauce accounted for 32.8% of the market. Pixian bean paste is a unique, regionally produced product. This product has developed rapidly in recent years, with its sales in 2018 approaching 10 billion CNY. Brands such as Dandan, Fan Saoguang, and Juancheng accounted for a large share, forming a certain industrial cluster through localized product standards.

2.3 Summary

In general, the total output of the Chinese Baijiu industry has declined over the past three years, but net profits have increased year by year. The rice wine industry has shrunk, and the output and profits of the seasoning wine

industry have grown. The annual output and profits of the condiment industry have increased over the past three years. In addition, the traditional fermented food industry has become increasingly concentrated, especially in the soy sauce and Chinese Baijiu industries, where the effects of large brands and single products have become increasingly significant [5]. Currently, traditional fermented food companies are becoming more innovative and technologically oriented, with increased investment in scientific research and the proportion of R&D personnel, while the number of scientific research platforms and independent R&D companies has increased to some extent. As shown in Table 2, although the Chinese Baijiu industry occupies the largest output value and profit, its R&D investment is relatively low (only 0.1%–0.6%). The second-ranked soy sauce industry has the highest proportion of R&D investment, ranging from 1.4% to 3%. Some leading Chinese Baijiu and soy sauce enterprises have issued numerous patents and have initially created an intellectual property design for core technologies. In terms of innovation platforms, the Chinese Baijiu and rice wine industries each have a national engineering technology center, and the Chinese Baijiu industry has five national enterprise technology centers. Only Hengshun Vinegar Inc. and Sichuan Dandan Group have been granted national-level enterprise technology centers in the condiment industry, while the soy sauce industry lacks a national-level R&D platform and only has a few provincial-level engineering centers.

3 Current status of intelligent manufacturing technology of traditional fermented food in China

The production of traditional Chinese fermented foods generally uses solid or semisolid fermentation processes to give the products a unique flavor. At present, fermentation with large tanks or tank trucks using high-level mechanization is found in the high-salt dilute soy sauce process, a small amount of rice wine production, and Xiaoqu liquor. However, most companies still use traditional solid-state fermentation methods. At the same time, the total costs of labor and energy in various industries have increased. Moreover, increased consumption and fierce global competition have prompted companies to improve their competitiveness through technological upgrades [6]. As a sector of the fermented food industry that has undergone a successful transformation, the beer industry has initially adopted digital manufacturing, implementing a three-chain brewing fusion of supply, manufacturing, and design. The soy sauce industry has also shifted toward green manufacturing, and leading companies generally have a relatively high level of green manufacturing technology [7]. In the initial research stage, we conducted various investigations on traditional fermented food companies. The results indicate that the Chinese Baijiu and soy sauce industries—the top two industries in terms of output value in the traditional fermented food industry—have invested more in the R&D of advanced technology and equipment. Therefore, we conducted a detailed analysis of these two industries and identified the main problems facing their transformation and upgrades.

3.1 Status quo of intelligent manufacturing in the Chinese Baijiu industry

Industries 2.0, 3.0, and 4.0 have different meanings and understandings in various manufacturing fields. For the traditional fermented food industry, the standard for entering Industry 2.0 is electrification and automation. The standard for entering Industry 3.0 is to apply electronics and information technology to improve traditional fermented food production automation. Industry 4.0 in the fermented food industry is the integration of the physical and virtual worlds. The main feature is digitization, networking, and the overall intelligence of the entire production process. Chinese Baijiu's solid-state fermentation process has generated problems such as imprecise fermentation mechanisms and negative online perceptions, leading to slow development at the mechanization and automation levels. Following the 11th Five-Year Plan—through the efforts of leading enterprises and industry associations, especially the 169 Plan and 158 Plan organized by the China Liquor Industry Association and the joint investment of funds—the resulting technology has been shared. This industry has made great progress in mechanized koji production, distillation, and waste treatment. As a result, mechanization, automation, and informatization in the entire Chinese Baijiu industry have greatly improved (Fig. 1). In terms of microbial fermentation, technical equipment for mechanized koji production has been developed. Koji accumulation has also resulted in automated mechanical production, and the Internet of things in the liquor fermentation tank has instilled online monitoring as part of the data. The postprocessing aspect of Baijiu production has reached a basic level of automated production, and management systems such as intelligent robot retort systems have been developed and employed (Fig. 1). Overall, Chinese Baijiu enterprises have achieved Industry 3.0 in terms of manufacturing. They have increased their investment in intelligent brewing workshops, production lines, and monitoring systems,

DOI 10.15302/J-SSCAE-2021.02.017

improving labor productivity and liquor yield. However, the fermentation stage of the pit is limited by its mechanistic analysis. Despite attempts to integrate the Internet of things in the pit, it is still in a semi-mechanized state.

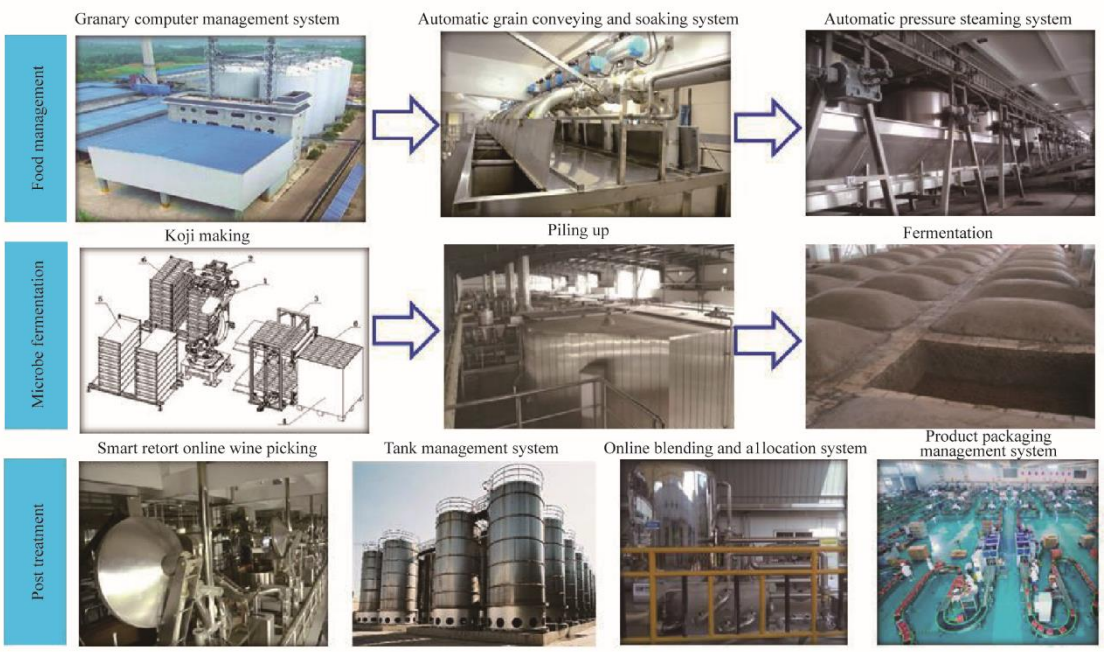

Fig. 1. Mechanization and automation of Chinese Baijiu brewing.

3.2 Status quo of intelligent manufacturing in the soy sauce industry

The traditional soy sauce brewing method is a high-salt solid-state fermentation process with low production efficiency. Based on the analysis of the brewing mechanism, a Japanese company designed a thoroughbred relay high-salt diluted state deep fermentation process and invented and applied a disc koji-making machine. Soy sauce production efficiency is now greatly improved, and the process is efficient and controllable, but the disadvantage is the loss of a small amount of flavor. Guangdong Province, China, has plenty of sunshine and limited temperature fluctuations. The Cantonese-style high-salt dilute soy sauce process is a sublation of Japanese technology. Leading soy sauce companies have abandoned the high-energy-consuming low-temperature fermentation process with yeast, adopting the late-stage sun-drying process to obtain the soy sauce flavor brought by the sun and increase production capacity. At present, soy sauce brewing has reached the initial stage of digital manufacturing, and it is already trying to integrate manufacturing chains and supply chains. Haitian Food, for example, has achieved automation in fermentation, brewing, filling, and storage. Digital manufacturing has been realized in some production sectors, where laser direct structuring, learning management system, manufacturing execution system, enterprise resource planning, intelligent three-dimensional warehouses, robotic palletizing systems, and extremely fast filling systems have been introduced. In addition, both Lee Kum Kee and Jiajia Food installed more than 2000 advanced online sensors that collect data in real time and have networked their entire work sections, reaching the initial stages of digital manufacturing in their factories.

3.3 Application status and patents of intelligent manufacturing technology

A comparative analysis of the patents and R&D investments of 57 major enterprises in the traditional fermented food industry across the country was performed. The intelligent manufacturing-related technical equipment of the entire traditional fermented food industry was mainly concentrated in packaging and filling. Intelligent manufacturing in the fermented food industry is still in its infancy, with most enterprises at the level of Industry 3.0 or below. As shown in Fig. 2, some large soy sauce companies are at the forefront of mechanization, automation, and digital manufacturing, reaching the industry 3.0 level and early stages of digital manufacturing. Most of the Chinese Baijiu and rice wine enterprises are between the industry 2.0 and Industry 3.0 levels. Some seasoning wine companies have adopted large-scale fermentation tanks to control production continuously and automatically, which is near the end of the Industry 3.0 scale. The technological level of the vinegar industry is

relatively diverse, from Industry 2.0 to digital manufacturing, and the technological level of each company is quite different. Most of the fermented sauce industry is at the industry level of 2.0, although a few enterprises have reached the industry level of 3.0. In addition, statistics indicate that 32% of fermented food companies did not use smart monitoring equipment, another 60% did not use smart production systems, 17% did not use industrial robots, 49% were not connected to the Internet, and 79% did not have automated warehouses (Fig. 3).

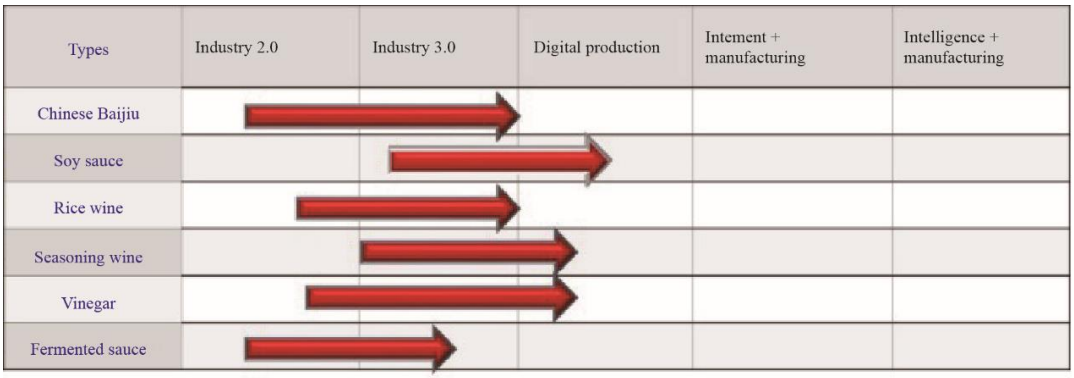

Fig. 2. The intelligent manufacturing levels of China's traditional fermented food industry.

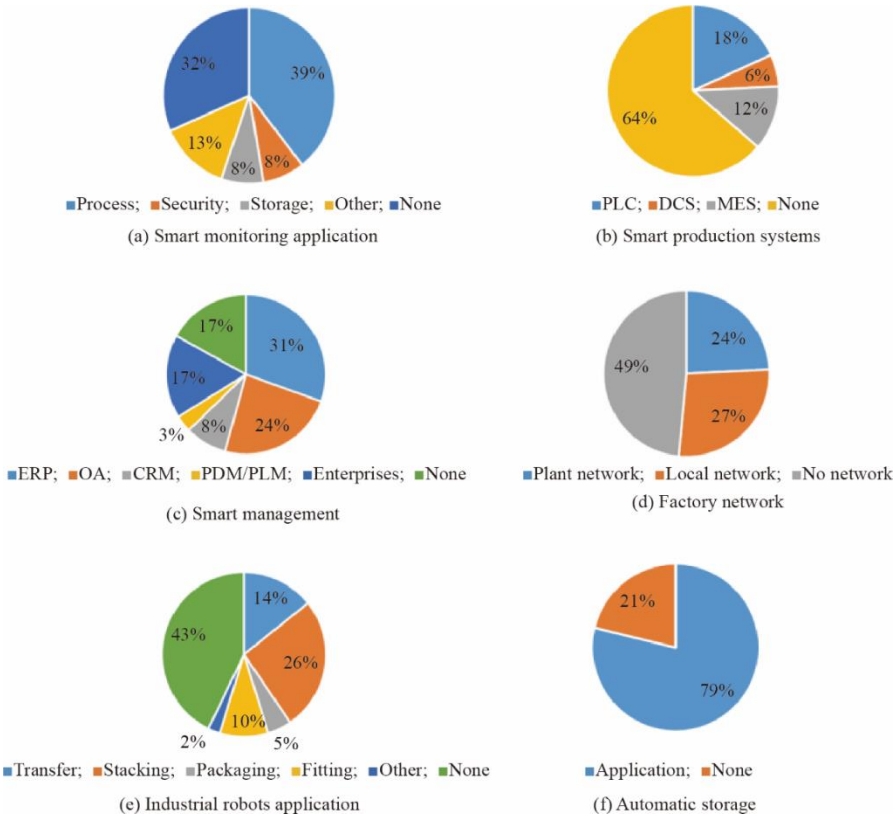

Fig. 3. Applications of related technologies and equipment in intelligent manufacturing of traditional fermented food companies. *Note:* OA refers to office automation; CRM refers to customer relation management; PDM/PLM refers to product data management/product lifecycle management.

4 Current status of green manufacturing technology in the traditional fermented food industry

The goal of green manufacturing is to minimize negative environmental impacts and maximize resource utilization during the entire lifecycle of a product, including design, manufacturing, packaging, transportation, and disposal, to coordinate and optimize the economic and social benefits of the company. In the list of 1407 green factories granted by the Ministry of Industry and Information Technology, 119 were from the food sector,

DOI 10.15302/J-SSCAE-2021.02.017

accounting for 8.5% of the total. The number of green traditional fermented food factories is small (only 23), accounting for a relatively small portion of the industry (1.6%). There are 16 Chinese Baijiu companies, three soy sauce companies, one vinegar manufacturer, and two pickle companies. Analysis of the data provided by research companies found that traditional fermented food companies mainly focus on improving resource utilization and cleaner production levels in terms of green manufacturing innovation—energy conservation and emissions reduction, recycling, and use of new energy sources, paying less attention to and green manufacturing technology innovation. Most of the current Chinese Baijiu, soy sauce, vinegar, and other enterprises have established standards for resource utilization-level evaluation indicators. The seasoning wine industry implemented a new group standard for grain-based seasoning wine in 2019. However, rice wine enterprises and fermented sauce enterprises have not established policies or standards for energy conservation and clean production.

The traditional fermented food industry produces large amounts of solid-liquid waste. The Chinese Baijiu industry generates distillers' grains rich in rice husks, the soy sauce industry produces a large amount of sauce residue, and rice wine enterprises and the seasoning wine industry generates distillers' grains and acidic wastewater. The main treatment technologies for solid waste include steam production from burning distiller grains or using distillers' grains as feed materials for cattle and sheep. In addition, many Chinese Baijiu companies have established raw material bases and return distillers' grains to the fields. Several Chinese Baijiu companies have established green parks to link primary, secondary, and tertiary industries. A few examples are the Moutai Ecological Circular Economy Industrial Demonstration Park, Chishui River Ecological Restoration Park, and Yanghe Ecological Town [8]. There is no technical bottleneck for the soy sauce industry that is difficult to break through to realize green production in soy sauce factories. At present, leading soy sauce companies maintain relatively high R&D investment and a high level of green manufacturing technology [9]. For example, in terms of energy conservation and emission reduction, the Haitian Group has built energy-saving systems such as condensate recovery systems, secondary steam reuse for preheating, reclaimed water reuse, and compressor waste heat recovery. Overall, the green manufacturing of China's traditional fermented food industry is developing well, with the future technology upgrade goals mainly oriented toward green raw materials, clean production, waste recycling, and low-carbon energy.

5 Main challenges in upgrading the traditional fermented food industry

5.1 Insufficient investment in R&D and innovation and weak awareness of intellectual property protection

China's traditional fermented food industry has gradually evolved from a small workshop-style production model with a family unit to a highly industrialized factory production model. The emphasis on R&D, innovation, and investment has always been low throughout the industry development process. For example, the proportion of R&D investment in the condiment industry is between 1.4% and 3%, while the wine industry is only 0.1%–0.6%. Regarding intellectual property rights, the traditional fermented food industry has applied for 56 729 patents, of which 47.64% are design patents. Companies with the largest number of patents in the entire industry possess just over 900 patents, far lower than other industries.

5.2 High energy consumption, high environmental pressure, and imperfect manufacturing system

Green manufacturing aims to coordinate and optimize economic and social benefits throughout a product's life cycle. China's traditional fermented food industry has always faced high energy consumption, high pollution pressure, and insufficient application of new technologies. As for transformation and upgrades, the leading industrial enterprises focus on strengthening resource utilization and improving cleaner production, paying less attention to the research and innovation of core green manufacturing technologies. SMEs lack sufficient upgrade capabilities and are basically in a passive stage, and development across smaller industries within the fermented food industry is uneven.

5.3 Intelligent manufacturing transformation is in its infancy, and core equipment is highly dependent on imports

The production technology level of China's traditional fermented food industry is generally low, but the craftsmanship is strong. The fermentation stage has the characteristics of an uninterrupted manufacturing process, but the microbial reaction constantly changes the system components. Intelligent manufacturing systems need to have real-time perception and active and independent decision-making capabilities that require advanced technology and equipment constructed in a complex system. Additionally, a complete set of available equipment is difficult to obtain, and more than 60% of the

key equipment depends on imports. Therefore, China's traditional fermentation industry lacks a clear and operable intelligent upgrade path. The intelligent manufacturing system is incomplete, research on key common technologies is insufficient, and the research and application of the connection between software and hardware are not yet mature.

5.4 Industry dispersion is high, and corporate profitability is insufficient

Based on the historical evolution of the industry, the fermented food industry has a discrete distribution, with a high proportion of SMEs, a low overall technical level, and weak anti-risk capabilities. In recent years, the total output value and profits of China's traditional fermented food industry have maintained an annual growth rate of 3%–5%, but there are large differences between different industries. For example, in the Chinese Baijiu industry, which has the largest volume in the industry (approximately 70% of the total volume), the total sales in the past five years were approximately 550–650 billion CNY, and the overall loss of the industry was close to 10%. The COVID-19 pandemic severely impacted SMEs in 2020. Many closures and bankruptcies occurred, which had a huge impact on China's traditional fermented food industry.

6 Countermeasures and suggestions

6.1 Promoting breakthroughs in key theories and technical equipment

Research on the traditional fermentation mechanism plays an important role in the intelligent and green upgrades of the industry. This information can support the research and development of standard technologies in the fermentation process and elucidate key mechanisms [10]. The key to competitiveness in the traditional fermented food industry is the microbial community alternation and metabolic regulation mechanism, especially the main functional flora. Using modern interdisciplinary biology, bioinformatics, and computer science, the effective regulation of fermentation technology based on inherited technology and product characteristics can be realized. As shown in Fig. 4, using synthetic microbial community technology and living cell high-throughput screening technology can promote a new generation of intelligent and efficient brewing production technology based on the essence of brewing to promote brewing standardization. This process is key to promoting an intelligent transformation. In addition, it is also important to establish critical industry-wide technology plans and strategic layouts, which will permit the traditional fermented food industry to guide upstream and downstream companies to participate in key common technology research. These policies include strengthening research on the key mechanisms of the fermentation process; strengthening the intelligent modeling of the operational dynamics of the fermentation industry driven by big data; strengthening the basic theory of "algorithm + technology" integration; promoting the integration and coordinated development of technology and equipment; and promoting the integration of general technology, equipment, and control system theory and technology with fermented food.

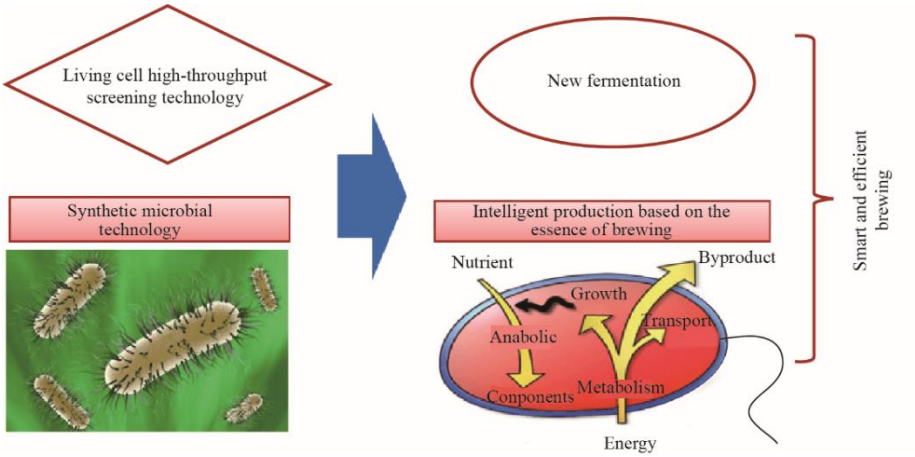

Fig. 4. A new generation of efficient and intelligent brewing pathways.

6.2 Establishing unified standards and promoting end-to-end integration

Fig. 5 shows the future Industry 4.0 factory example, in which a variety of software and hardware systems efficiently manage the supply chain, manufacturing and logistics, channels, consumers, and product design and

DOI 10.15302/J-SSCAE-2021.02.017

development. As a result, data from each section of the factory can be collected through various sensors to achieve digitization of the factory and the smart product manufacturing. Therefore, the underlying data collection and communication methods are crucial, and it is necessary to strengthen uniform standards across different sections. At the international level, it is necessary to integrate national concepts (integrated standardization), system-level standardization (use-case standardization), and standardized connection protocols (communication standardization). Additionally, a uniform data specification and uniform data calibration must be established [11]. It is also necessary to strengthen software and hardware compatibility between different hardware suppliers, establish standardized data structures and interfaces between each unit, sort out and unify the data processing methods of each process link, and finally achieve cross-industry coordination under the same industrial chain. In terms of policy, it is necessary to focus on supporting the standard formulation and revision work and, at the same time, to apply the achieved results of the standard construction work to the pilot enterprises in a timely manner to form a working model of formulation, verification, and promotion, thereby guiding enterprise upgrades based on intelligent manufacturing.

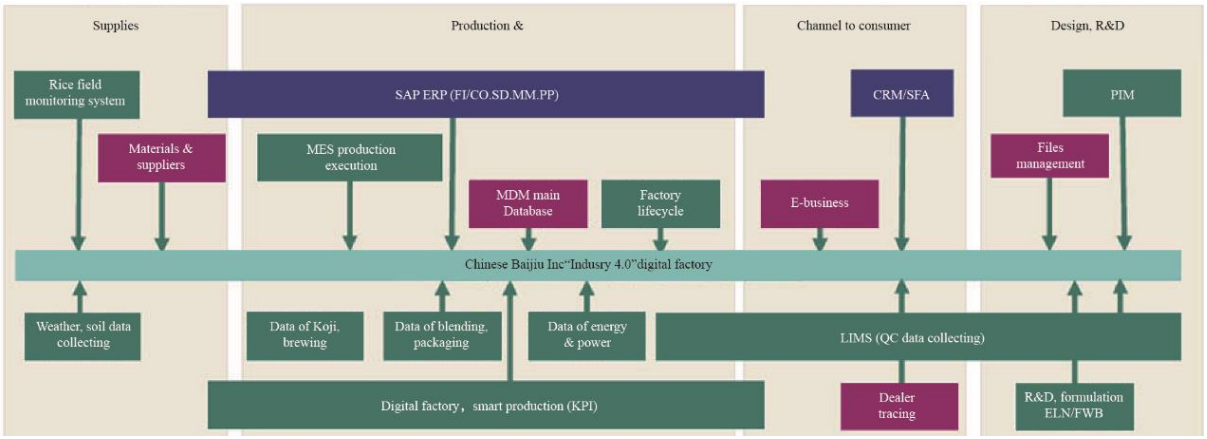

Fig. 5. Future "Industry 4.0" demonstration factory for traditional fermented food companies.

Note: SAP refers to system applications and product; SFA refers to sales force automation; PIM refers to personal information management; MDM refers to mobile device management; LIMS refers to laboratory information management system; QC refers to quality control; KPI refers to key performance indicators.

6.3. Cultivating a new shared manufacturing model and promoting technological advancement

The sharing economy model should be promoted for SMEs and industries that cannot upgrade. The technical equipment level of the industry should be improved through capacity sharing. The principal measures include sharing manufacturing, innovation, and service capabilities. By cultivating a shared manufacturing model, it is possible to gather diverse intellectual resources in society and develop multi-factory collaborative manufacturing services, which can reduce transformation and upgrade costs for SMEs and improve the technical level of the industry in a relatively short time. By establishing various forms of industry–university–research cooperation, a new mode of sharing innovative capabilities will integrate various resources and serve SMEs. In terms of service capacity sharing, we can integrate social service resources and explore an intensified, intelligent, and personalized development mode within the common service needs of enterprises, such as logistics and warehousing, product testing, equipment maintenance, inspections, supply chain management, data storage, and analysis. In addition, although the sharing model promotes technological progress, it is also necessary to prevent future product homogeneity and the non-specialization of production processes. On one hand, the model manages part of the overall planning; on the other hand, the model encourages innovation and protects intellectual property rights.

6.4. Innovating green manufacturing and cleaner production technologies to improve resource utilization

This strategy includes strengthening the research and development of full-value utilization technology of brewing raw materials and integrating them into every section based on ensuring or improving the flavor quality of fermented food, integrating the application of extraction, separation, drying, and various types of processing technologies to effectively improve all steps of production [12]. In addition, a variety of technology integration methods can be adopted to improve energy efficiency: adopting advanced energy-saving technology and equipment, strengthening technical energy-saving strategies, and promoting the elimination and updating of

backward equipment; developing innovative production technology to reduce energy consumption per unit of industrial added value, such as high-yield strains and heat pump technology; establishing energy management systems to improve energy conservation and primary energy utilization; and developing renewable resources and green factories with waste recycling and low-carbon energy.

References

[1] Consumer Goods Industry Division, Ministry of Industry and Information Technology. 2018 China food industry [M]. Beijing: China Light Industry Press, 2019. Chinese.

[2] Consumer Goods Industry Division, Ministry of Industry and Information Technology. 2017 China food industry [M]. Beijing: China Light Industry Press, 2018. Chinese.

[3] Consumer Goods Industry Division, Ministry of Industry and Information Technology. 2016 China food industry [M]. Beijing: China Light Industry Press, 2017. Chinese.

[4] Zhan J, Chen J. Current status and research progress of Chinese traditional fermented food industry [J]. Biotechnology & Business, 2015 (4): 11–16. Chinese.

[5] Wang Y C. Work report of the fifth (expanded) meeting of the fifth council of China wine industry association [J]. Liquor-Making Science & Technology, 2017 (5): 17–30. Chinese.

[6] Zhou J, Li P G, Zhou Y H, et al. Toward new-generation intelligent manufacturing [J]. Engineering, 2018, 4(1): 11–20.

[7] Deloitte Enterprise Risk Management Service. Long-term driving force in the era of Industry 4.0: Integration of informatization and industrialization [M]. Shanghai: Shanghai Jiao Tong University Press, 2015. Chinese.

[8] Zhao F Q. Study on the sustainable development of liquor industry in China [D]. Beijing: CASS Graduate School (Doctoral dissertation), 2014. Chinese.

[9] Li L, Bai F W. The present situation and development prospect of Chinese soy sauce [J]. Modern Food, 2018, 5(9): 24–31. Chinese.

[10] China Institute of Electronic Technology Standardization, Shenzhen Huazhi Intelligent Manufacturing Technology Co., Ltd., Northeast University. White paper on process intelligent manufacturing [R]. Beijing: China Institute of Electronic Technology Standardization, 2019. Chinese.

[11] Li B H, Chai X D, Zhang L, et al. Accelerate the development of intelligent manufacturing technologies, industries, and application under the guidance of a new-generation of artificial intelligence technology [J]. Strategic Study of CAE, 2018, 20(4): 73–78. Chinese.

[12] Research Group of *Chinese Academy of Engineering Green Manufacturing Development Strategy Research*. Advancing green manufacturing for ecological civilization: Research on green manufacturing strategies in China [J]. Strategic Study of CAE, 2017, 19(3): 53–60. Chinese.