

Tradition and Modernity: Evolution of China Liquor-making Technology

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Abstract This study provides a comprehensive review of the characteristics of liquor brewing. It introduces the status and history of liquor in Chinese culture, analyzes the background and significance of the liquor industry, and explores in detail the traditional and modern liquor brewing processes, with a focus on the key steps and technologies. Traditional liquor brewing involves five steps: steaming, fermenting, brewing, aging, and bottling, while modern techniques involve large-scale production and continuous operation to make liquor brewing more scientific and efficient. This review will discuss two different brewing methods, traditional brewing technology and modern industrialized production, and compare their advantages and disadvantages and development trends. The traditional traditional artisanal pays attention to the selection of raw materials and the control of processing process, which is complex in technique and requires a lot of labor and time costs. However, the produced liquor has mellow taste, rich aroma and long taste, and has high quality and cultural value. However, modern industrialized production mode pays attention to large-scale, standardized production process and automatic equipment, which can greatly reduce labor and time costs and improve production efficiency and output. However, the taste of liquor made from it is lower than that of traditional manual production mode, so more process improvement and innovation are needed. In addition, the study summarizes the current status and problems of liquor brewing technology and proposes future development trends, such as emphasizing environmentally friendly and sustainable practices, ensuring health and safety, and promoting intelligent development. As technology advances and market demands change, liquor brewing technology is continuously updated and upgraded. In the future, liquor brewing technology will focus more on environmentally friendly, healthy, safe, and intelligent development. This review comprehensively expounds the evolution of liquor brewing technology from traditional to modern, which has certain reference value for deeply understanding the development trend and cultural connotation of liquor industry.

Keywords Baijiu production; Process characteristics; Tradition and modernity; Technological innovation; Development trends

Liquor is an important component of traditional Chinese culture and one of the significant symbols of Chinese national culture. The development history of liquor brewing techniques is ancient, and for thousands of years, it has carried the cultural heritage and wisdom of the Chinese nation. This overview aims to provide a comprehensive study of the brewing techniques of liquor from traditional to modern, in order to further understand the development trends and cultural significance of the liquor industry. As an alcoholic beverage that has been passed down through generations in China, liquor has always played a crucial role.

With the rapid growth of the Chinese liquor industry, the inheritance and innovation of liquor brewing techniques have become important research directions. Understanding the characteristics and cultural significance of liquor brewing techniques is of great significance for promoting the sustainable development of the liquor industry and further enhancing the international influence of Chinese wine culture. This overview provides a comprehensive review of the characteristics of liquor brewing techniques, serving as a reference and basis for a deeper understanding of the development trends and cultural significance of the liquor industry. Additionally, this overview will focus on exploring the application of traditional craftsmanship and modern technology in liquor brewing, as well as the comparison and evolution of traditional and modern techniques (Fan and Qian, 2005).

Chinese liquor, as a gem of Chinese wine culture, has always been loved by domestic and foreign consumers. In the process of modernization, the brewing techniques of Chinese liquor have been continuously evolving and developing. It not only preserves the essence of traditional brewing techniques but also incorporates the advantages of modern technology, forming a unique brewing technology system. This technology system has not only greatly improved the quality and taste of Chinese liquor but also facilitated the rapid development of the Chinese liquor industry.

The brewing techniques and flavors of liquor are adapted to local conditions, reflecting the regional cultural characteristics of different areas. Liquors from different regions have variations in the materials used, water sources, fermentation agents, and brewing techniques during the brewing process, resulting in differences in taste and aroma. For example, Moutai liquor from Guizhou Province uses sorghum as the main ingredient and employs traditional mud fermentation process and special water quality. It has a rich and aromatic flavor, showcasing the distinctive regional cultural characteristics of Guizhou. On the other hand, Lang liquor from Hubei Province is made from high-quality wheat and sorghum, utilizing traditional pit fermentation techniques. It has a mild taste and a fragrant aroma, reflecting the regional cultural characteristics of Hubei.

With the development of technology, the liquor brewing techniques are also constantly innovating and improving. Some companies and research institutions are introducing advanced brewing equipment and techniques to enhance the brewing process, improve production efficiency, and product quality. For instance, Moutai Group in Guizhou Province has introduced the "Six-in-One" brewing system, which integrates the processes of brewing, fermentation, distillation, storage, blending, and packaging, thereby improving production efficiency and product quality (Ye et al., 2021). As consumer awareness of health increases, there is also a growing demand for healthy alcoholic beverages.

This study aims to explore the evolutionary process of Chinese liquor brewing techniques from a historical perspective, starting from ancient traditional manual brewing to modern automated production processes. Through these discussions, we hope to provide a deeper understanding of the evolution of Chinese liquor brewing techniques and shed light on the impact of modernization on the Chinese liquor industry, as well as its future development trends.

By studying the characteristics of liquor brewing techniques, we can not only gain a deeper understanding of the rich connotations of Chinese wine culture but also provide insights and inspiration for promoting the sustainable development of the liquor industry. This research overview will contribute to a better understanding of the development and cultural significance of the liquor industry, offering practical and theoretical value. It can also provide a certain reference for other brewing industries.

1 Characteristics of Liquor Brewing Techniques

Liquor is one of the traditional alcoholic beverages in China, and its brewing techniques have a long history and are closely intertwined with Chinese culinary culture. The traditional liquor brewing process is intricate and time-consuming, requiring a significant amount of human and material resources. However, the resulting liquor has a mellow taste, rich aroma, and unique flavor characteristics, which is one of the reasons why it is favored by consumers. Different regions have their own unique regional characteristics of liquor. For example, the Jiangsu-Zhejiang region is known for its light aroma liquor, Sichuan wine is famous for its sauce aroma, and Guizhou is renowned for its strong aroma liquor. Each flavor is closely related to the local climate, soil, and brewing traditions. Modern liquor brewing techniques are more automated and technologically advanced compared to traditional techniques. They can improve production efficiency and ensure consistency and stability in the products. With the continuous progress of technology, liquor brewing techniques are constantly innovating and developing. In the future, we can expect the application of more new technologies and processes in liquor production.

1.1 The traditional liquor brewing process and its characteristics

The traditional liquor brewing process is a complex craft that has evolved over thousands of years, resulting in a unique set of techniques. This traditional brewing method has been passed down through generations and is regarded as a precious heritage of Chinese culture. The process of liquor brewing mainly includes steps such as cleaning and processing of grains, saccharification, fermentation, distillation, and aging. The control and handling of these stages have a significant impact on the quality and taste of the liquor (Hu et al., 2021).

The main raw materials for liquor production are grains such as sorghum (*Sorghum bicolor* L.), wheat (*Triticum aestivum* L.), and corn (*Zea mays* L.). liquor brewing is based on natural grains and undergoes various processing steps such as cleaning, draining, soaking, and others to achieve the appropriate moisture content and quality (Cheng et al., 2014). The quality of the brewing materials directly affects the quality and alcohol yield of the liquor. liquor is a traditional Chinese alcoholic beverage with over 10 different aroma types. Each aroma type has its own distinctive style, which is not only attributed to unique brewing techniques but also influenced by the choice of raw materials. In traditional techniques, sorghum is considered the best raw material for brewing as it imparts the most aromatic qualities, mainly due to the presence of tannins in the sorghum bran.

In liquor brewing, saccharification is the process of converting starch into sugars. Generally, the starch molecules in grains are large and cannot be directly utilized by microorganisms like yeast. Therefore, it is necessary to convert the starch molecules into sugars through saccharification. This process involves the addition of fermentation agents such as malt to facilitate the microbial breakdown of starch molecules into sugars. During saccharification, parameters such as temperature and time need to be controlled to ensure efficient and high-quality conversion of starch into sugars.

After saccharification, the saccharified starch solution is mixed with yeast fermentation agents and placed in a fermentation tank for fermentation. The fermentation period generally lasts around 15 to 20 days, although it can vary depending on the specific brewing technique and type of wine. The fermentation process in liquor brewing requires careful control of factors such as temperature, humidity, and oxygen. Precise control of fermentation conditions is crucial to ensuring stable wine quality and excellent flavor. liquor brewing often employs solid-state fermentation, where the fermentation material remains insoluble in the fermentation liquid. This brewing method minimizes the contact area between the fermentation material and the fermentation liquid, which helps maintain process stability and consistency in the quality of the wine produced.

Next, the fermented liquid is subjected to distillation. The distillation process of liquor typically involves multiple distillations to increase the alcohol content and improve the taste of the wine (Hu et al., 2021). Storage and aging are also crucial factors that affect the quality of liquor. The final liquor product undergoes storage and aging, often in ceramic jars or wooden barrels. It requires long-term aging, ranging from several years to several decades, allowing the interaction between the wine and the materials inside the containers to develop a unique flavor profile. The more extended the aging period, the more mellow and rich the flavor of the liquor becomes (Figure 1).

The production of liquor predominantly relies on traditional methods, and certain processes require manual operation. These traditional techniques preserve the characteristics of historical and cultural heritage, endowing liquor with unique historical value and cultural significance. The traditional liquor brewing process is a complex undertaking that demands strict control over each step. It encompasses rich cultural connotations and traditional craftsmanship. As an integral part of Chinese traditional culture, the brewing process of liquor represents the wisdom and history of Chinese culture. Moreover, the inheritance and development of this craft are crucial factors driving the sustainable growth of the Chinese liquor industry. Therefore, research and promotion of traditional liquor brewing techniques contribute to a deeper understanding of the rich connotations of Chinese wine culture and provide insights and inspiration for the development of the liquor industry.



Figure 1 The finished liquor produced by traditional distillation process

1.2 The process and characteristics of modern liquor brewing techniques

The modern liquor brewing process mainly includes steps such as raw material processing, saccharification and yeast fermentation, distillation, aging and storage, blending and filtration, and bottling. Compared to traditional methods, modern techniques are more scientific and efficient. They incorporate automated control systems and eco-friendly materials and processes, which enhance production efficiency, product quality, and reduce environmental pollution. Through continuous optimization of raw material formulas and process flows, modern brewing techniques result in liquors with a more robust and delightful flavor. The produced liquors are clearer, purer, and possess a unique taste.

Traditional liquor primarily uses sorghum as the main ingredient, while contemporary liquor utilizes a variety of cereal grains such as wheat, corn, rice, quinoa (*Chenopodium quinoa* Willd), adzuki beans, and others. This diversification of grain ingredients enriches the taste and flavors of liquor (Figure 2). The processing methods of grains also differ between traditional and modern liquor production. Traditional liquor involves manual or stone milling, while modern liquor employs mechanized processing using equipment such as rice polishers and flour mills. This enhances production efficiency and helps retain the nutritional components of the grains.



Figure 2 A variety of miscellaneous grains that can be used as raw materials

In the process of saccharification and fermentation, traditional liquor production uses natural yeast, while modern liquor production often utilizes purified and cultivated pure strains of yeast. This improves fermentation efficiency, stability, and allows for better control over the flavor and quality of the wine. During the distillation of the fermentation liquid, traditional liquor is distilled using traditional wooden or clay stills (Figure 3A), while modern liquor employs stainless steel or copper stills (Figure 3B). This enhances distillation efficiency and sanitary conditions, as well as allows for better control over the wine's taste and aroma. Furthermore, modern liquor

refining processes incorporate new filtration equipment and techniques such as activated carbon filtration and nanofiltration. These methods effectively remove impurities and off-flavors, thereby improving the quality and taste of the wine. In the bottling stage, traditional liquor is often manually filled, which can result in variations in bottle capacity, higher loss, and lower efficiency. In contrast, modern liquor factories generally employ machine bottling, significantly improving filling efficiency and accuracy.



Figure 3 Different distillers used in traditional and modern times

Note: A: Traditional wooden and muddy distillers; B: Modern stainless steel and copper still

The modern liquor brewing process is continuously innovating and progressing, resulting in improved production efficiency while ensuring the quality and taste of the wine. This advancement has made the liquor industry more scientific, efficient, and sustainable. Modern brewing techniques employ advanced automation control systems that enable precise control over parameters such as temperature, humidity, and pH during the brewing process, ensuring stable product quality (Figure 4). Additionally, modern brewing techniques prioritize environmental protection by using eco-friendly materials and processes, reducing environmental pollution. The progress and innovation in these technologies have made modern liquor brewing more efficient, scientific, and environmentally friendly (Hong et al., 2020).



Figure 4 Modern liquor brewing equipment

1.3 The crucial stages and key techniques of liquor brewing process

The selection and processing of raw materials, saccharification and fermentation, distillation techniques, aging and storage, and quality control are crucial stages and key techniques in the liquor brewing process. They play a decisive role in determining the quality and taste of liquor. In the process of liquor brewing, these stages and techniques need to work together in order to produce high-quality liquor. With the continuous development of technology, the liquor brewing process is constantly innovating and improving. The use of new materials, the application of new enzymes and distillation techniques, and advancements in environmental and quality control

have provided more possibilities and opportunities for enhancing the quality and taste of liquor (Kang and Xu, 2012).

The raw material is the foundation of liquor production. The selection and processing methods of the raw material directly impact the quality and taste of the liquor. When it comes to selecting raw materials, factors such as the type, quality, and origin of the grains need to be considered. For example, different varieties of sorghum exhibit variations in several aspects such as starch content, protein content, fat content, tannin content, thousand grain weight, and ash content. These differences are more pronounced between northern and southern glutinous sorghum varieties. The quality of the brewing sorghum becomes visually apparent during the cooking process and ultimately reflects in the quality of the liquor. Comparative studies have shown that southern sorghum exhibits higher water absorption rate, viscosity, and gelatinization rate after cooking compared to northern sorghum. This indicates that southern sorghum is not only more easily utilized by microorganisms but also reduces energy consumption during the cooking process, demonstrating excellent brewing characteristics. Raw materials are the foundation of liquor brewing, and the selection and processing methods of raw materials directly impact the quality and taste of the wine. When it comes to selecting raw materials, factors such as the type, quality, and origin of the grains need to be considered. Different varieties of sorghum, for example, exhibit variations in several aspects such as starch content, protein content, fat content, tannin content, thousand grain weight, and ash content. These differences are particularly evident between northern and southern glutinous sorghum varieties. The quality of the brewing sorghum becomes visually apparent during the cooking process and ultimately reflects in the quality of the liquor. Comparative studies have shown that southern sorghum exhibits higher water absorption rate, viscosity, and gelatinization rate after cooking compared to northern sorghum. This indicates that southern sorghum is not only more easily utilized by microorganisms but also reduces energy consumption during the cooking process, demonstrating excellent brewing characteristics.

In terms of processing, appropriate processing equipment such as grinding discs, millstones, and rice mills need to be selected for the crushing of raw materials to ensure processing efficiency and the quality of the powder. Saccharification and fermentation are crucial in liquor brewing, and the quality and efficiency of fermentation directly affect the taste and quality of the wine. During the fermentation process, factors such as temperature, humidity, yeast quality, and proportions need to be carefully controlled to ensure fermentation stability and the desired flavor of the wine.

After fermentation, the fermented grain residue needs to undergo separation of alcohol and other flavorful substances. During the distillation process, factors such as temperature, pressure, and flow rate need to be carefully controlled to ensure the alcohol content and the desired taste and aroma of the wine. Once the brewing process is completed, the liquor enters the stage of aging and storage. During storage, factors such as temperature, humidity, and light exposure need to be carefully regulated to ensure the quality and taste of the liquor remain intact (Wang, 2022).

There are numerous crucial stages and key technologies in the liquor brewing process, and each stage requires careful control. The purpose of these measures is to ensure the control of liquor quality, as quality control is crucial in the brewing process and determines the safety and quality of the wine. Traditional liquor brewing primarily relies on experience and traditional techniques to control quality, while modern liquor brewing incorporates a series of strict control measures such as standardized production processes, raw material quality control, and standardized production operations (Xu et al., 2023). These measures contribute to better safeguarding the quality and safety of liquor. In addition, modern liquor brewing also employs new detection technologies such as gas chromatography, liquid chromatography, and mass spectrometry. These technologies enable more accurate detection of harmful substances and contaminants in the wine, ensuring its safety and quality (Figure 5).



Figure 5 Detection of liquor quality by modern technology

2 The Improvement and Innovation of Modern Liquor Brewing Processes

With the continuous development of technology and the introduction of modern production processes, significant improvements and innovations have been made in modern liquor brewing. These improvements and innovations mainly involve aspects such as raw material selection, technological advancements, application of new equipment, and innovation in quality control techniques. The improvement and innovation of modern liquor brewing processes not only contribute to enhancing the quality and taste of liquor but also accelerate the brewing cycle, reduce production costs, and meet consumer demands. However, it is important to note that the application of modern processes may also have some negative effects, such as potential impacts on the taste and quality of liquor. Therefore, when applying modern liquor brewing processes, it is necessary to consider various factors comprehensively in order to develop the optimal brewing plan and achieve the best wine taste and quality.

2.1 The application of novel ingredients and yeast strains

In terms of ingredient selection, in modern liquor brewing processes, not only traditional grain-based ingredients such as sorghum, wheat, and corn are still widely used, but there is also an emergence of applications using novel ingredients. Examples of these novel ingredients include peanuts (*Arachis hypogaea*), adzuki beans (*Vigna angularis* (Willd.) Ohwi & H. Ohashi), and sweet potatoes (*Ipomoea batatas* (L.) Lam.). The use of these novel ingredients not only enhances the taste and quality of liquor but also helps to expand the market and meet consumer demands. Compared to traditional liquor, peanut-based liquor is considered a "niche product" in the eyes of consumers. It has a rich flavor, strong aroma, and a mellow taste, making it more suitable for consumers who enjoy a strong and flavorful experience. Common brands of peanut-based liquor include "Luoyang Laojiao" and "Langjiu Peanut" Wine. Adzuki bean-based liquor primarily uses adzuki beans as the main ingredient, offering a refreshing and sweet taste with certain nutritional value. Common brands of adzuki bean-based liquor include Shikumen, Xifeng, and Dongjiu. As for sweet potato-based liquor, as the name suggests, it mainly utilizes sweet potatoes as the raw material. Although not widely popular due to personal taste preferences, it is available in the market. Brands like Guotai, Jinfo, and Jintangli have introduced sweet potato-based liquor. Sweet potato-based liquor has a unique flavor and possesses certain health benefits. The existence of various flavored alcoholic beverages holds value as they cater to different consumer preferences. With an increasing demand from consumers for both taste and nutritional value in liquor, modern liquor brewing is increasingly experimenting with different plant-based ingredients to meet consumer needs.

The application of novel yeast strains is becoming increasingly widespread in modern liquor brewing processes. These novel yeast strains not only improve fermentation efficiency and stability but also contribute to controlling the taste and quality of the wine. According to surveys, common novel yeast strains found in the market include koji yeast, pectinase yeast, and Sichuan pepper yeast. Koji yeast is a widely used novel yeast strain in liquor

brewing. It enhances alcohol fermentation efficiency and stability while also reducing methanol content in the wine. Common varieties of koji yeast include black koji and white koji. Pectinase yeast is a novel yeast strain capable of degrading pectin. It improves alcohol fermentation efficiency and stability while also enhancing the taste and concentration of the wine. Common varieties of pectinase yeast include pectinase yeast strains. Regarding Sichuan pepper yeast, it is a novel yeast strain that produces the aroma of Sichuan pepper. It allows for the control of the flavor and quality of the wine. Common varieties of Sichuan pepper yeast include Sichuan pepper yeast strains. The application of novel yeast strains in modern liquor brewing processes is receiving increasing attention. These novel yeast strains not only improve the quality and taste of the wine but also allow for control over its flavor and quality. They have broad prospects for application.

2.2 Improvement and innovation in automation control technology

Today, modern liquor brewing processes utilize advanced automation control systems to achieve precise control over parameters such as temperature, humidity, pH value, and more, thereby improving the quality and stability of liquor. These improvements and innovations provide new impetus and guarantees for the development of the liquor industry. For example, Yanghe Distillery, a company in China, has introduced automation control technology in the liquor brewing process, enabling automated control over steps such as saccharification, fermentation, and distillation, resulting in improved production efficiency and product quality. The application of these technologies has played a significant role in establishing Yanghe Distillery as one of the leading enterprises in the Chinese liquor industry. Moutai Group, a renowned Chinese liquor company, has also extensively applied automation technology in its production process. Moutai Group utilizes intelligent production lines that enable automated production and process control (Li et al., 2022). Each stage of the production line is equipped with automation equipment and sensors, facilitating automated control and monitoring, thereby enhancing production efficiency and quality (Figure 6). Keeping pace with the times, Moutai Group has also adopted artificial intelligence (AI) technology to achieve automation control and optimization in the production process. Through AI technology, data analysis and processing can be conducted, optimizing the production process and improving product quality and production efficiency. Both Yanghe Distillery and Moutai Group in China have demonstrated outstanding applications of automation technology. Through the application of automation technology, they have achieved automated control and optimization of the production process, resulting in improved product quality and production efficiency (Zhang, 2001; Zhang and Wu, 2012).



Figure 6 Moutai packaging intelligent production line

The improvement and innovation in modern liquor automation control technology provide new impetus and guarantees for the development of the liquor industry. By introducing advanced automation control systems, precise control over various parameters during the brewing process can be achieved, enhancing product quality and stability while reducing manual intervention and lowering production costs.

2.3 The application of data-driven management and new equipment

The application of data-driven management and new equipment in the modern liquor industry is a significant indicator of its continuous progress and development.

Data-driven management is an essential aspect of modern liquor brewing processes. It involves comprehensive monitoring and management of the brewing process, enabling fine-tuning and increased efficiency. Through data-driven management, better control over the quality and taste of the wine can be achieved, leading to improved production efficiency and product quality. For example, Yanghe Distillery has established a complete data-driven management system for the production process, encompassing production planning, process control, quality monitoring, and other data management aspects. This system enables real-time monitoring of various indicators during the production process, and the data is analyzed and processed to facilitate timely actions, ensuring product quality and production efficiency. As a result, it also enhances the product's quality and competitiveness in the market.

Regarding the application of new equipment, modern liquor brewing processes utilize new equipment such as continuous brewing equipment and microbial fermentation devices, which enhance production efficiency and quality while reducing environmental pollution. For instance, Wuliangye Group introduced the world's first microbial fermentation device, which allows for precise control of parameters such as temperature, humidity, and oxygen supply during the fermentation process, thereby improving product stability and taste. Additionally, the application of continuous brewing equipment has significantly increased production efficiency and quality while reducing manual intervention and environmental pollution associated with traditional processes. It also saves energy and raw materials (Pan et al., 2019).

The application of these technologies can greatly enhance production efficiency, product quality, and stability, while reducing environmental pollution, providing new impetus and guarantees for the sustainable development of the liquor industry.

2.4 Technological innovations in liquor quality control

With the continuous progress of modern technology, there have been constant innovations in liquor quality testing techniques. Modern liquor quality inspection technologies not only assess traditional indicators such as alcohol content, acidity, and amino acids, but also detect trace elements and volatile organic compounds, providing a more comprehensive evaluation of liquor quality. Sensing technology is one of the key technologies in liquor quality control. By utilizing various sensors, it enables real-time monitoring of parameters such as temperature, humidity, and pH during the production process, thus controlling the parameters to ensure product quality and stability. Nanotechnology is an emerging technology in liquor quality control and a significant innovation. It utilizes nanomaterials such as nano-silver and nano-silica to improve the microscopic structure of the wine, thereby enhancing its taste and quality. These innovations enable effective control of liquor quality while laying the foundation for the sustainable development of the liquor industry.

3 Analysis of the Development of Chinese Liquor Brewing Techniques

3.1 The current status and issues of liquor brewing technology

Liquor brewing technology is constantly evolving and innovating, and while it has achieved certain accomplishments, it still faces certain issues and challenges. The current status and problems directly impact the development of the liquor industry. Only through technological innovation and management innovation can these problems and challenges be addressed, thus promoting the sustainable development of the liquor industry.

Traditional liquor brewing techniques have a history of thousands of years and have developed and improved over the years, forming a relatively mature production technology and process. Traditional techniques still remain the mainstream in liquor brewing. However, with the continuous progress of science and technology, an increasing number of advanced technologies are being applied in liquor production. For example, the application of modern

molecular biology, fermentation engineering, measurement and control technology, artificial intelligence, and other technologies has brought new ideas and methods to liquor brewing. The key to producing high-quality liquor lies in the selection and quality of raw materials. Therefore, more and more liquor producers are now using high-quality raw materials such as premium rice, wheat, and corn to produce high-quality liquor. With the advancement of industrial production, an increasing number of liquor production companies are transitioning to industrialized production. They are adopting modern brewing equipment, automated production processes, and advanced management models to improve production efficiency and product quality.

Although traditional liquor brewing techniques have a long history, they also have certain limitations, such as low production efficiency, high production costs, and inconsistent product quality. These issues need to be addressed through technological innovation. The gradual application of advanced technologies brings along environmental concerns. liquor production requires a significant amount of water resources and energy, and some traditional production processes generate a large amount of wastewater and exhaust gas, causing environmental pollution. It is necessary to adopt more environmentally friendly production processes to address these issues.

3.2 The development trends of liquor brewing technology

With the continuous progress of technology and the increasing demand for quality, health, and cultural aspects, liquor brewing technology is also constantly innovating and developing. The most obvious trend is efficiency and automation. The equipment and processes involved in liquor brewing are continuously updated and upgraded towards higher efficiency, automation, and intelligence. For example, advanced brewing systems, intelligent monitoring systems, and automated material handling systems can improve production efficiency and product quality while reducing labor and resource waste.

Simultaneously, with the trend of globalization, liquor brewing technology is also moving towards internationalization. For example, actively introducing advanced brewing equipment and technologies from abroad, learning from advanced brewing concepts and experiences, promoting the international development of the Chinese liquor industry, and also emphasizing the promotion of Chinese traditional culture and liquor culture to make international consumers understand and appreciate Chinese liquor.

3.3 The future development direction of the liquor brewing industry

The future development trend of the liquor brewing industry is multifaceted, emphasizing efficiency, automation, sustainability, and health consciousness, as well as quality, personalization, and internationalization. With the increasing awareness of consumer health, liquor brewing technology is evolving towards greener and healthier practices. For example, using natural, pollution-free, and organic ingredients without chemical additives to produce healthier and greener liquor. There is also a focus on the nutritional value and health benefits of the wine, resulting in the development of low-alcohol, low-sugar, low-calorie, and other healthier liquor options to meet consumer health demands. This requires the liquor brewing technology to develop towards quality and personalization. For instance, using high-quality ingredients, precision brewing equipment, and meticulous blending processes to produce more mellow, delicately textured, and aromatic liquor. Additionally, there is an emphasis on personalized customization, producing liquor that caters to the individual taste preferences, health requirements, and cultural demands of different consumers.

4 Summary and Outlook

Chinese liquor, as one of the world's six major distilled spirits, possesses a unique brewing technique that is an important part of Chinese culture. The characteristics of liquor brewing technology are primarily reflected in its complex production process, rich historical tradition, strict selection of ingredients, and distinct regional characteristics. As an important component of Chinese culture, liquor brewing technology can drive the international development of the Chinese liquor industry and enhance the brand image of liquor.

Through the analysis of the evolution and current status of Chinese liquor brewing techniques, it can be observed that both traditional and modern brewing techniques have their unique advantages and disadvantages. Traditional brewing techniques have the advantages of simple ingredients, simple processes, and unique flavors. However, they also face challenges such as low production efficiency, poor stability, and inconsistent product quality. On the other hand, modern brewing techniques offer advantages such as high production efficiency, stable product quality, and complex processes. However, they also have higher requirements for ingredients, higher technical barriers, and environmental impacts. Therefore, in practical production, it is necessary to choose different brewing techniques based on different needs and market conditions. Through in-depth research on the evolution of liquor brewing processes, a better understanding of Chinese traditional culture and the development trends of the liquor industry can be achieved. This understanding can further enhance the quality and international competitiveness of Chinese liquor.

The Chinese liquor industry will continue to develop and innovate, integrating traditional and modern techniques to improve product quality. As people's awareness of health and environmental protection continues to increase, the future characteristics of liquor brewing processes will emphasize more on green practices, health consciousness, and environmental friendliness. In terms of ingredient selection, liquor producers will focus more on choosing pollution-free and organic materials in the future. Advanced ingredient processing technologies will be employed to reduce environmental pollution and enhance the quality of the wine. Regarding brewing techniques, liquor producers will continue to explore and apply new brewing technologies in the future, such as biotechnology, high-pressure techniques, membrane separation technologies, and more. These advancements aim to improve brewing efficiency and quality while reducing energy consumption and wastewater discharge.

In addition, intelligent production will also become an important trend in future liquor brewing. By adopting technologies such as the Internet of Things (IoT), big data, and artificial intelligence (AI), the digitization and intelligentization of the production process can be achieved, thereby improving production efficiency, product quality, and cost reduction. The future liquor brewing processes will place more emphasis on green practices, health consciousness, and intelligentization to drive the sustainable development of the Chinese liquor industry and enhance the quality of liquor.

Authors' contributions

ZJY is the project leader responsible for literature collection, paper writing, and finalizing the manuscript. The author read and approved the final manuscript.

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