Rice Sour Soup: Traditional Craftsmanship, Microbial Flora and Future Development

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Abstract. As a traditional fermented food with strong ethnic characteristics in Southwest China, rice sour soup carries rich dietary culture and historical connotations. This article systematically reviews the current research status and development trajectory of rice sour soup. Firstly, it traces its historical lineage and cultural value stemming from the dietary practices of ethnic minorities, clarifying its position in the inheritance of regional dietary culture. Secondly, it analyzes the industrialization of traditional production techniques and modern processes. Furthermore, it summarizes the research progress on fermentation microbial communities, focusing on elucidating the dominant role of lactic acid bacteria as the core functional strain in the formation of product acidity and basic flavor, as well as the synergistic enhancement mechanism of auxiliary bacterial communities such as yeast and acetic acid bacteria. Finally, in response to the bottlenecks in the industrialization development of rice sour soup, it proposes internet-based marketing strategies. It aims to provide a comprehensive reference for the cultural inheritance, process optimization, strain application, and market promotion of rice vinegar soup, and promote the sustainable innovation and transformation of this traditional fermented food in the modern food industry.

Keywords: Rice sour soup; Process; Microbiota.

1. Introduction

Fermented foods, as an important part of human dietary culture, occupy an important position in the global dietary system with their unique flavor, long-shelf life and potential health value. As a highly representative traditional grain fermented food in the Miao ethnic group area of Southwest China, rice sour soup has a history of hundreds of years in its production and consumption. It is not only a key seasoning for enhancing freshness and flavor in daily cooking but also carries regional folklore and dietary wisdom. Rice sour soup, also known as white sour soup, is a fermented food made with rice as the main raw material, through natural inoculation or fermentation with traditional Laotan (old jar) fermentation cultures. Its traditional production process relies on experience passed down from generation to generation, and it typically features local sourcing of ingredients, simple operation, and no standardized procedures. However, for a long time, the academic community has not yet formed a systematic and in-depth theoretical system for the research on rice sour soup. Based on this, this article systematically reviews the development history and regional cultural background of rice sour soup, analyzes the key links and technical points of its traditional production process, clarifies the core functional bacterial species and microbial community evolution rules during the fermentation process, explains its nutritional value and health effects, and combines the current development trend of the food industry to look forward to future research directions and industrialization paths, aiming to provide references for the inheritance of traditional craftsmanship, the improvement of scientific theory, and the sustainable development of the industry.

2. The Historical and Cultural Background of Rice Sour Soup

As a traditional delicacy with strong regional characteristics and ethnic customs, rice sour soup has accumulated profound historical and cultural connotations over the years. Its history can be traced back to thousands of years ago, closely linked to the life and migration of the Miao ethnic group.

In ancient times, Guizhou did not produce salt, but due to its complex terrain and isolated transportation, it was extremely difficult to transport salt, resulting in high salt prices and making it difficult for ordinary people to obtain it. "The Continuation of the Records of Guizhou" records that Guizhou is located between Yunnan and Sichuan, and it alone does not produce salt. It only relies on Sichuan for supply. Since the source is far away, the price is high. In order to cope with the shortage of salt, the ancestors of the Miao ethnic group developed a dietary seasoning method of "using acid instead of salt" to compensate for the taste and physical needs. In their long-term life practice, they accidentally discovered that the remaining rice soup would produce sour taste after natural fermentation, which not only added flavor to food, but also had the effect of promoting secretion of saliva and strengthening the stomach, and increasing appetite. Therefore, they gradually explored the method of making sour soup with rice soup fermentation, and rice sour soup came into being. In Guizhou, there's a local saying: “If you don’t eat sour food for a day, even good dishes lose their flavor; for two days, you won’t feel like touching any meal; for three days, you’ll stagger when walking.' This shows how deeply the local people love 'sour food”.

Regarding the origin of rice sour soup, there is a touching legend in the ancient songs passed down orally by the Miao people. According to the legend, in ancient times, there lived a girl named Ana on the Miaoling Mountain. She was not only beautiful, but also skilled in singing and dancing, and could brew delicious wine. The wine she brewed had the fragrance of orchids and was as clear as mountain springs. Young men from hundreds of miles around came to court her. For those who came to court her, the girl would pour a bowl of self-brewed wine. Those who were not chosen would feel the wine was very sour and cold in their hearts, but they were reluctant to leave. As night approached, the lush sound of the reed pipe and the bursts of mountain songs filled the air. Young men sing folk songs around their houses, calling for the girls to meet them. The girls have to sing back from behind the fences: "Sour, sour soup; sour, sour lad. Listen to my song, oh sour lad! Betel nuts bear no fruit in March; orchid grass has no fragrance in September. If love is true, mountain spring turns to fine wine; if love is false, fine wine turns to sour soup..."Although the legend cannot be confirmed by conclusive historical records, it vividly reflects the close connection between rice sour soup and the survival history of the Miao ethnic group.

With the development of the times, the consumption scope of rice sour soup has been continuously expanded, and the market demand has increased significantly, making it a highly promising folk flavor condiment for development.

3. Traditional Process of Making Rice Sour Soup

As a traditional fermented food in the southwest region (mainly in Guizhou), rice sour soup is made based on the local climate and characteristics of ingredients, with family manual operation as the core. It is a fermented food made through natural inoculation or traditional old jar fermentation. Its traditional production process relies on experience passed down from generation to generation, and is characterized by using local materials, simple operation, and no standardized process. The core lies in the conversion of starch and sugar through natural fermentation, forming a unique sour and fragrant flavor.

In accordance with DBS52/056-2021 "Local Food Safety Standard for Sour Soup" issued by the Health Commission of Guizhou Province, white sour soup is a liquid compound condiment. It is processed with rice and/or wheat, corn, soybeans, etc. as the main raw materials, with or without auxiliary materials such as edible salt and spices added, through processes including inoculation with fermentation cultures or natural fermentation, filtration, and sterilization.

There are two common traditional production techniques for white sour soup today: fermentation using white sour soup stock as a starter (natural fermentation) and fermentation using direct-vat set (DVS) bacterial powder. When using white sour soup stock as a starter, first prepare rice pulp and pour it into a clean, oil-free fermentation container. Add mature white sour soup stock in proportion, stir well, seal the container, and place it in a suitable temperature environment away from light for natural fermentation. During this period, you can occasionally open the container to stir and release gas. After an appropriate period of time, when the soup turns milky white and has a mild sour taste, the finished rice sour soup is ready. When making white sour soup with DVS bacterial powder, first prepare rice pulp and pour it into a clean fermentation container. Add DVS bacterial powder according to the product instructions, stir thoroughly, seal the container, and place it in an environment with a suitable temperature for fermentation. Stir appropriately during the process. After an appropriate period of time, when the soup has a proper sourness, no off-flavors, and a rice aroma, the white sour soup is finished.

Zhao Chengxin et al. compared two fermentation methods of white sour soup through experiments: the control group (Group NF-7) used 60% white sour soup mother liquor as the starter, and the process involved grinding rice soaked for 6 hours (with a rice-to-water ratio of 1:24) into pulp, boiling it for gelatinization, cooling it down, and then inoculating it for fermentation; the experimental group (Group IF-7), based on the control group, additionally added direct-vat-set (DVS) Lactobacillus casei and Lactobacillus plantarum (in a ratio of 1:1, with the viable count of each being approximately 1×10^{10} CFU/g), and the total number of lactic acid bacteria after inoculation was controlled to be about 2×10^{7} CFU/mL [1]. The results showed that compared with the naturally fermented Group NF-7, Group IF-7 had advantages including higher total acid content and lactic acid bacteria count as well as better sensory evaluation, higher contents of beneficial bioactive substances such as L-lactic acid and lysine which enhanced nutritional and health-care value, lower contents of harmful metabolites like N-acetylputrescine leading to higher safety, and a faster fermentation rate that could shorten production time and ensure flavor stability; its disadvantage, however, was that the contents of alcohols (such as propanol and ethanol) and esters (such as propyl acetate and propyl propionate) in Group IF-7 were lower than those in Group NF-7, and it only had an advantage in the content of acids (such as acetic acid and propionic acid).

Wang Rong et al. used rice pulp saccharified liquid as the raw material and a mixed fermentation culture of Lactobacillus rhamnosus, Lactobacillus zeae, and Lactobacillus plantarum to determine the optimal fermentation conditions for rice sour soup through single-factor experiments and response surface methodology (RSM) [2]. The results showed that the process parameters optimized by RSM were as follows: fermentation time of 104 h, inoculum size of 5%, fermentation temperature of 36°C, and pH value of 6.6. The resulting acidity was (9.48±0.08) g/L, which was basically consistent with the model-predicted acidity of 9.43 g/L. Subsequently, the researchers took self-made rice sour soup as the research object, adopted the accelerated storage test method, and established kinetic and thermodynamic mathematical models between the centrifugal precipitation rate and color difference value of rice sour soup, and its sensory score, storage temperature, and storage time, based on the changes of the physical and chemical indexes of rice sour soup over time at different storage temperatures. These models served as prediction models for the product. The average CV (coefficient of variation) errors of the prediction models for centrifugal precipitation rate and color difference value were calculated to be 13.46% and 6.07%, respectively, both <15%. Therefore, the prediction models established based on the two indexes (centrifugal precipitation rate and color difference value) of rice sour soup during storage can well predict the storage stability of rice sour soup at 25–45°C, providing a reference for predicting its storage stability.The DI (discrimination index) values of principal component analysis (PCA) for electronic nose and electronic tongue were both >99%, which indicates that there are significant differences in the volatile odor components and flavor components of rice sour soup stored at different temperatures for 180 days.

Additionally, Wang Rong et al. conducted an inoculation experiment—using a 1:1:1 ratio of Lactobacillus rhamnosus, Lactobacillus zeae, and Lactobacillus plantarum with a mixed inoculum size of 5 mL/100 mL—to investigate the effects of different ratios of glutinous rice, non-glutinous rice, and high-gluten flour on the quality of rice sour soup [3]. They analyzed the correlations between quality indexes and optimized the rice pulp preparation process. The results showed that the raw material ratio with the highest sensory score was 2:1:1 (glutinous rice: non-glutinous rice : flour). The optimal process conditions for rice pulp liquefaction were as follows: liquefaction time of 30 min, liquefaction temperature of 85°C, liquefying enzyme addition of 40 U/g, and pH of 6. The optimal process conditions for rice pulp saccharification were: saccharification time of 1.5 h, saccharification temperature of 60°C, saccharifying enzyme addition of 1,000 U/g, and pH of 5.

4. Fermentation Strain of Rice Sour Soup

Jiang Ping et al. isolated and identified the microbial flora from 5 samples of Kaili "sour soup" [4]. The results showed that symbiotic microorganisms including yeasts, lactobacilli, acetic acid bacteria and leuconostocs existed in the mature fermented sour soup. These microorganisms form a symbiotic microbial system of Kaili "sour soup" and undergo ethanol, lactic acid and acetic acid fermentation. This combined fermentation process endows Kaili "sour soup" with a unique, cool and refreshing taste and flavor.

Xiao Tiantian et al. analyzed the microbial community structure in the traditional fermented white sour soup of the Miao nationality using high-throughput sequencing technology [5]. Under the guidance of this technology, they directionally screened the dominant microorganisms in the white sour soup. The results showed that the main dominant microorganisms in the white sour soup were Lactobacillus, Acetobacter and Kluyveromyces, with a total of 80 bacterial strains screened out. Shi Min et al. found through their research that the proportions of the main functional bacteria in "Kaili rice sour soup" were 68.36% for lactobacilli, 14.90% for leuconostocs, 16.19% for acetic acid bacteria, 0.41% for Candida utilis and 0.14% for Saccharomyces cerevisiae. Overall, the microorganisms in the fermentation strains of rice sour soup mainly include three categories: lactic acid bacteria, yeasts and acetic acid bacteria [6].

Liu Na et al. found in their study that the main bacterial phylum and fungal phylum of traditional Chinese fermented rice-acid soup were Firmicutes and Ascomycota, respectively, containing 62 bacterial genera and 57 fungal genera [7]. The dominant bacterial genera were Lactobacillus, Acetobacter, and Prevotella; the dominant fungal genera were Naumovia, Pichia, Candida, and Saccharomyces. In rice-acid soup, L-lactic acid had the highest concentration among organic acids, followed by malic acid, acetic acid, citric acid, oxalic acid, and tartaric acid. Volatile flavor compounds (VFCs) contributed significantly to its flavor, mainly including 10 types of substances such as ethyl acetate, ethanol, acetic acid, and propanoic acid (including 1-octen-3-ol, 2,3-butanedione, etc.). There were 6 genera of microorganisms closely associated with key organic acids, including Lactobacillus, Acetobacter, and Pichia; 4 genera of microorganisms associated with VFCs, including Acetobacter and Prevotella. Among them, 6 genera of microorganisms (such as Lactobacillus and Pichia) showed a significant positive correlation with lactic acid in rice-acid soup; Kluyveromyces, Saccharomyces, and Emericella showed a significant positive correlation with ethanol and ethyl acetate.

4.1. Lactic Acid Bacteria

Lactic acid bacteria ferment carbohydrates in the raw materials of white sour soup to produce a large amount of lactic acid, which lays the foundation for the basic sour taste of white sour soup. Meanwhile, they also metabolize and generate organic acids such as acetic acid and propanoic acid, as well as flavor substances like alcohols and esters. These substances endow white sour soup with a unique taste that is mellow, refreshing and rich in layers. Additionally, lactic acid bacteria can help maintain gastrointestinal function and promote the absorption of nutrients.

Cao Xuhong screened the dominant bacterial strains from the white sour soup of the Miao nationality in Guizhou, isolated 3 strains of Lactobacillus casei, and optimized the fermentation conditions (inoculum size: 10^7 cfu/mL, temperature: 35°C) [8]. The results showed that the natural fermentation cycle was significantly shortened, and the stability and sensory quality of the sour soup were improved.

Xiao Tiantian et al. conducted a single-strain inoculation experiment to simulate white sour soup fermentation using dominant Lactobacillus strains [5]. They screened out strains with good glucose-lowering ability, acid-producing capacity, and sensory scores. Through molecular biological identification, these strains were identified as 4 strains of Lactobacillus casei and 2 strains of Lactobacillus paracasei. Zhao Chengxin et al. found three strains in Kaili white sour soup—Lactobacillus paracasei L7, Lactobacillus casei L17, and Lactobacillus plantarum L31—all of which had good acid-producing capacity [9]. Among them, Lactobacillus plantarum L31 showed the strongest acid-producing capacity; Lactobacillus paracasei L7 and Lactobacillus casei L17 had similar acid production and acid-producing rate, with a longer acid-producing period, making it easier to control the acid production process. At the normal gastric juice acidity of pH 2.5, all three strains could survive and had the chance to enter the intestine to exert probiotic effects. At the fasting gastric juice acidity of pH 1.5, only strain L31 could survive with a low survival rate, but its viable count still reached the minimum required for lactic acid bacteria to exert probiotic effects. This indicates that Lactobacillus plantarum L31 has good acid tolerance and potential for further development.

Liu Na screened a high acid-producing strain, L. paracasei H4-11, through her research on rice-acid soup. This strain has a strong ability to produce L-lactic acid, which is beneficial to the formation of the unique sour taste of rice-acid soup [10]. It can also be co-fermented with K. marxianus L1-1 to produce rice-acid soup with better flavor and stronger antioxidant capacity. Inoculating Lactobacillus paracasei H4-11 (and Kluyveromyces marxianus L1-1) into fermented rice-acid can enhance the antioxidant capacity of mouse serum. Lactobacillus paracasei H4-11 and Kluyveromyces marxianus L1-1 may have a synergistic effect in improving the antibacterial function of intestinal flora in mice, reducing the number of harmful microorganisms, and increasing the number of beneficial microorganisms [11].

Jiang Ping et al. isolated 3 strains of lactobacilli from the culture of "sour soup" [4]. These lactobacilli did not grow on ordinary nutrient agar. On modified Czapek medium, pinhead-sized, red and translucent colonies were observed, with transparent calcium-dissolving zones around them. On MRS medium, the colonies were grayish-white, flat with irregular edges, and 0.5–1 mm in diameter. Microscopic examination showed that they were Gram-positive, non-spore-forming large bacilli, arranged singly or in chains.

Additionally, the changes in the lactic acid bacteria community during the fermentation of "Kaili Sour Soup" follow a certain pattern. At the initial stage of fermentation, the number of Lactobacillus colonies is 0.57×10^7 CFU/mL; it reaches the highest on the 4th day, with the colony count being 2.00×10^7 CFU/mL; on the 6th day, it drops to 1.41×10^7 CFU/mL, and further decreases to 1.10×10^7 CFU/mL on the 8th day [6].

4.2. Yeast

During the fermentation of rice sour soup, yeast, as a core microorganism, metabolizes carbohydrates to produce ethanol, carbon dioxide, and various esters. These substances collectively contribute to the rich taste and characteristic flavor of the beverage. Its metabolic activities simultaneously synthesize functional components such as β-glucan and secrete a variety of B vitamins. These active substances, working together with yeast cells, can regulate the balance of intestinal microecology, reduce the colonization of pathogenic bacteria through competitive inhibition, and enhance the body's immune response. This comprehensively improves the nutritional value and health benefits of rice sour soup.

Xiao Tiantian et al. conducted a simulated fermentation experiment of white sour soup by inoculating single strains from dominant yeast strains [5]. They screened out strains with good glucose-lowering ability, acid-producing capacity and sensory scores. Through molecular biological identification, these strains were identified as 8 strains of Saccharomyces cerevisiae, 2 strains of Kluyveromyces marxianus and 2 strains of Pichia sp

Through her research on rice sour soup, Liu Na screened out the strain K. marxianus L1-1 that produces ethyl acetate during the fermentation of rice sour soup [10]. This strain not only produces a variety of organic acids but also generates ethyl acetate—a key aroma compound in rice sour soup—which promotes the formation of the unique flavor of rice sour soup. Additionally, when co-fermented with L. paracasei H4-11, it produces rice sour soup with better flavor and stronger antioxidant capacity compared to that fermented by a single strain. Inoculating Kluyveromyces marxianus L1-1 (and Lactobacillus paracasei H4-11) into fermented rice sour soup can enhance the antioxidant capacity of mouse serum. Lactobacillus paracasei H4-11 and Kluyveromyces marxianus L1-1 may have a synergistic effect in improving the antibacterial function of the intestinal flora in mice, reducing the number of harmful microorganisms, and increasing the number of beneficial microorganisms [11].

Jiang Ping et al. isolated Candida utilis and Saccharomyces cerevisiae from the culture of "sour soup" [4]. The colonies grew on malt extract agar plates, appearing round, smooth, with neat edges and a milky white color, and had a diameter of approximately 2 mm.

Studies have shown that at the initial stage of fermentation, the colony count of Candida utilis was 0.57×10^5 CFU/mL. On the 4th day of fermentation, the colony count increased to 1.22×10^5 CFU/mL, decreased to 0.47×10^5 CFU/mL on the 6th day, and further dropped to 0.39×10^5 CFU/mL on the 8th day. At the initial fermentation stage, the colony count of Saccharomyces cerevisiae was 0.17×10^4 CFU/mL. It rose to 4.87×10^4 CFU/mL on the 4th day, decreased to 3.00×10^4 CFU/mL on the 6th day, and fell to 2.50×10^4 CFU/mL on the 8th day [6].

Yeasts start to grow during the fermentation process of sour soup. Among them, fermentative yeasts grow and reproduce throughout the primary and secondary fermentation stages until all carbohydrates are consumed. Yeasts play a significant role in the flavor, quality, and storage of fermented sour soup. Under anaerobic conditions, yeasts break down glucose into ethanol and carbon dioxide through glycolysis. Ethanol plays an important role in the post-ripening process of fermented sour soup and contributes to the production of a large number of aroma compounds. Since the growth and reproduction of yeasts occur when sugars are completely consumed, if the long-term fermentation process is not effectively controlled, the alcohol content in the sour soup will affect its normal flavor. In addition, the reproduction of some yeasts (such as Pichia sp.) can form a white film or white spots on the product surface and produce an unpleasant sour odor. These issues will seriously affect the appearance and quality of the product. Therefore, the fermentation of yeasts should be controlled during the sour soup fermentation process to ensure it proceeds normally [12].

4.3. Acetobacter

Acetobacter colonies are needle-tip sized, round, with a smooth surface, and moist to semi-transparent. There is a transparent dissolution zone around the colonies. Microscopic examination shows that they are Gram-negative, non-spore-forming bacilli. The bacterial cells are oval or rod-shaped, straight or slightly curved, and mostly exist singly.

In the fermentation of rice sour soup, Acetobacter is a key microorganism for forming its typical sour taste and functional properties. It oxidizes ethanol to acetic acid, laying the foundation for the product's sour flavor. Meanwhile, it produces esters such as ethyl acetate, enriching the aroma layers. This process significantly reduces the pH value of the system, effectively inhibiting the growth of miscellaneous bacteria and ensuring fermentation safety. The acetic acid produced and its metabolites also endow the product with potential health values, including regulating blood sugar, anti-oxidation, and improving lipid metabolism, which collectively constitute the unique flavor and functional characteristics of white sour soup.

Jiang Ping et al. isolated 5 strains of Acetobacter from the culture of "sour soup". The isolated Acetobacter strains do not grow on nutrient agar [4].

Additionally, the changes in the acetic acid bacteria community during the fermentation of "Kaili Rice Sour Soup" follow a certain pattern. At the initial stage of fermentation, the colony count is 0.61×10^6 CFU/mL; on the 2nd day, it is 1.18×10^6 CFU/mL; the colony count reaches 7.80×10^6 CFU/mL (note: the original text does not specify the day for this peak value); on the 8th day, it drops to 3.03×10^6 CFU/mL [6].

4.4. Leuconostoc

In rice sour soup, Leuconostoc produces lactic acid, acetic acid, and carbon dioxide through the heterofermentative lactic acid pathway. These substances together form the basic sour taste and refreshing texture of the product. Meanwhile, volatile compounds such as ethyl acetate and diacetyl generated by the metabolism of this bacterium significantly enhance the aroma complexity of the product. Furthermore, the glucan synthesized by Leuconostoc can effectively improve the viscosity and texture of the product. The organic acid system produces not only endows the product with a typical flavor, but also exhibits multiple functional properties such as inhibiting miscellaneous bacteria and antioxidation. These properties directly affect the sensory quality and functional attributes of the product.

Jiang Ping et al. isolated 5 strains of Leuconostoc from the culture of "sour soup", and these strains did not grow on nutrient agar. On agar medium, they could form pinhead-sized, circular, smooth, moist, light grayish-white and translucent colonies [1]. The colonies had a diameter of approximately 1.0 mm, were circular in shape, with a convex center, neat edges, smooth surface, moist texture and translucent appearance. Microscopic examination showed they were Gram-positive cocci, mostly arranged in pairs, and a few in chains, with no spores. At the initial stage of fermentation, the colony count of Leuconostoc was 0.70×10^6 CFU/mL. It reached the maximum on the 6th day, with a colony count of 6.93×10^6 CFU/mL, and then decreased to 3.00×10^6 CFU/mL on the 8th day [6].

During the mixed fermentation process, Leuconostoc acts as a key initiating microflora and reproduces rapidly in the early stage of fermentation. It rapidly produces organic acids, carbon dioxide and exopolysaccharides through heterofermentation, which effectively lowers the environmental pH value and creates an anaerobic environment for subsequent microflora. As fermentation proceeds, the environmental pH value decreases gradually. Leuconostoc mesenteroides become increasingly sensitive to acid, is gradually inhibited, and eventually dies. At this point, Lactobacillus brevis and Lactobacillus plantarum, which have high acid resistance, proliferate rapidly and produce a large amount of lactic acid, thus making them the dominant fermentation bacteria [12].

5. Marketing Feasibility of Rice Sour Soup

Currently, the public's understanding of rice sour soup is often limited to its use as a hot pot base and condiment. The market influence of rice sour soup health drinks, which possess regional characteristics, remains relatively limited. Given its inherent nature of being natural, healthy, and green, this product aligns well with modern consumers' demands for beverages and holds potential market opportunities. If internet thinking can be applied to identify the precise product positioning and target audience of rice sour soup products, coordinate promotion between backend R&D and frontend sales, adopt O2O-based promotion and marketing channels, and integrate traditional promotion and sales models, rice sour soup health drinks (positioned as functional beverages) can quickly penetrate the national market.

6. Conclusion

This review summarizes that the current research focuses on rice sour soup mainly centers on the structure of microbial communities and the analysis of their functions. It has been confirmed that lactic acid bacteria are the core functional bacteria, while auxiliary microbial groups such as yeast participate in flavor synergy, and the correlation between microbial communities and product quality has been initially established. However, there remains a key scientific issue unresolved in existing studies: the temporal succession law of microbial communities and the mechanism of metabolic interaction during the fermentation process have not been clarified. Specifically, there is a lack of accurate tracking of the temporal changes in microbial communities at different fermentation stages, and the regulatory effect of environmental factors on microbial communities has not been systematically elucidated. These gaps result in insufficient controllability of the fermentation process.

In future research, priority could be given to strengthening the application of multi-omics technologies and constructing a dynamic map of microbial communities throughout the entire fermentation cycle to clarify the metabolic mechanism. Meanwhile, it is necessary to expand diversified product forms such as ready-to-use seasonings and functional beverages and develop standardized bacterial preparations and industrialized processes to solve the problem of quality instability in traditional manual fermentation. In addition, the value of rice sour soup as a product integrating food and medicine can be explored by combining regional culture. Through geographical indication protection and branded packaging, the traditional product can be promoted to upgrade into a national consumer product category.

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