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Study on Sensory Quality and Flavor Characteristics of Jiangxiang Baijiu Produced by Different Fermentation Techniques

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Abstract: As a representative of traditional Chinese distilled liquor, the unique flavor of Sauce Flavor Baijiu is closely related to its brewing techniques. This study systematically explored the sensory quality and flavor characteristics of Sauce Flavor Baijiu produced by different fermentation techniques through sensory evaluation, gas chromatography analysis, and multivariate statistical methods. The results indicated that the techniques of Chuansha, Suisha, Kunsha, and their blends significantly influenced the concentration and proportion of flavor compounds in Baijiu, subsequently altering its aroma and taste. Specifically, Chuansha Baijiu exhibited weaker aroma and thinner taste; Suisha Baijiu presented certain complexity and a softer taste; while Kunsha Baijiu boasted a strong aroma and full-bodied taste. This study established a scientific quality evaluation system for Sauce Flavor Baijiu, providing theoretical foundations and technical support for the optimization of brewing techniques and improvement of Baijiu quality.

Keywords: Distilled Liquor; Sauce Flavor Baijiu; Chuansha; Suisha; Kunsha; Blends.

1. Introduction

Baijiu, as a traditional Chinese distilled liquor, holds a long history and profound cultural connotations, serving as one of the important carriers for the inheritance of Chinese traditional culture[1,2]. Sauce-flavor Baijiu, one of the four fundamental aroma types of Baijiu, is renowned for its unique sensory qualities and complex brewing process[3,4]. With the improvement of people's living standards and changes in consumption concepts, the requirements for Baijiu quality have also escalated[5,6]. Consumers are no longer solely satisfied with sensory experiences but also focus on the scientific analysis of flavor characteristics and drinking comfort[7].

Sauce-flavor Baijiu is distinguished by its long brewing cycle, intricate production process, and unique flavor profile[8-10]. Its distinctive sauce aroma originates from the unique brewing technique known as the "12987" process: one production cycle per year, two feedings, nine cookings, eight fermentations, seven distillations, along with the "four high" characteristics of high-temperature curing, high-temperature stacking, high-temperature fermentation, and high-temperature distillation[11]. These complex processes not only endow Sauce-flavor Baijiu with abundant flavor compounds but also shape its unique flavor profile[12-14].

However, the current evaluation of Sauce-flavor Baijiu quality heavily relies on sensory descriptions and empirical judgments, lacking a systematic scientific evaluation system[15]. While sensory evaluation is intuitive and important, it suffers from issues such as strong subjectivity and significant individual differences, making it difficult to ensure the objectivity and accuracy of evaluation results[16,17]. Therefore, establishing a scientific data-based quality evaluation system for Sauce-flavor Baijiu is particularly crucial[18].

In terms of flavor characteristics, Sauce-flavor Baijiu contains a rich array of flavor compounds, including alcohols, aldehydes, acids, esters, and various other compounds[19,20]. The types, contents, and proportional relationships of these flavor compounds in Sauce-flavor Baijiu determine its unique flavor profile[21,22]. However, current research on key flavor compounds in Sauce-flavor Baijiu is not sufficiently deep, lacking systematic analysis and validation[23,24].

Moreover, with people's pursuit of a healthy lifestyle, the drinking comfort of Baijiu has also become a focal point of attention[25]. Drinking comfort is not only related to consumers' sensory experiences but also directly influences their recognition and loyalty to Baijiu brands. Therefore, studying the drinking comfort of Sauce-flavor Baijiu is equally significant[26,27].

This research aims to systematically analyze the sensory qualities and flavor characteristics of Sauce-flavor Baijiu produced through different processes, combine modern analytical techniques and multivariate statistical methods, reveal the sensory characteristics and flavor material basis of Sauce-flavor Baijiu, and establish a scientific quality evaluation system. Additionally, this study will explore the drinking comfort of Sauce-flavor Baijiu and its related factors, providing scientific evidence and technical support for enhancing the quality and market competitiveness of Sauce-flavor Baijiu. Through this research, we hope to gain a more comprehensive understanding of the unique charm of Sauce-flavor Baijiu and promote the sustained and healthy development of the Sauce-flavor Baijiu industry.

2. Materials and Methods

2.1. Experimental Samples

The Baijiu samples were taken from a famous wine enterprise in Moutai Town, and these samples were located in the famous wine belt of Chishui River, as shown in Table 1.

Table 1. Samples information

Serial Number	Name	Alcohol%voL	Process	Year of production	Place of production
1	JJ1	52.1	Chuansha	2020	Moutai Town, Renhuai City, Zunyi City, Guizhou Province, China
2	JJ2	52.8	Chuansha	2020	Moutai Town, Renhuai City, Zunyi City, Guizhou Province, China
3	JJ3	52.5	Chuansha	2020	Moutai Town, Renhuai City, Zunyi City, Guizhou Province, China
4	JJ4	52.1	Suisha	2020	Moutai Town, Renhuai City, Zunyi City, Guizhou Province, China
5	JJ5	52.4	Combination of Suisha and Kunsha	2020	Moutai Town, Renhuai City, Zunyi City, Guizhou Province, China
6	JJ6	52.5	Kunsha	2020	Moutai Town, Renhuai City, Zunyi City, Guizhou Province, China
7	JJ7	53.5	Kunsha	2020	Moutai Town, Renhuai City, Zunyi City, Guizhou Province, China

2.2. Instruments and Equipment

Table 2. Main instruments

Instrument Name	Model	Manufacturer
Sensitivity Balance	BSA822-CW	Sedori Scientific Instruments (Beijing) Co.
Electronic Analytical Balance	CP1502	Shanghai OHAUS Instrument Co
Electrothermal constant temperature water bath box	HH-S6A	Beijing Liwei Yongxing Instrument Co.
Gas Chromatograph	AutoSystem XL	PerkinElmer Inc.
Ultrasonic Cleaner	KQ500-E	Kunshan Ultrasonic Instrument Co.
Heating Magnetic Stirrer	EMS-9A	Tianjin Ounuo Instrumentation Co.
Capillary Chromatography Columns	CP-Wax 57CB(50m×0.25mm×0.2)	PerkinElmer Inc.
Nitrogen Blower	OA-SYS	Shanghai Anpu Scientific Instrument Co.
Ultrapure Water Systems	Aquaplore3S	Acorp Inc.

2.3. Experimental Reagents

The main reagents and samples used in this thesis are shown in Table 3.

Table 3. Main experimental reagents and drugs

Reagent Name	Specification	Manufacturer
n-Butyl Acetate	Chromatographic Purity	Shanghai McLean Biochemical Technology Co.
Anhydrous ethanol	Chromatographic Purity	Tianjin Fuchen Chemical Reagent Factory
Sodium hydroxide	Analytical Pure	Tianjin Beifang Tianji Chemical Reagent Factory

2.4. Professional Sensory Description Method

Establishment of the Sensory Evaluation Panel: The panel consisted of five national-level first-class Baijiu tasters, aged between 25 and 45, in good health.

In accordance with national standards for the sensory evaluation of Baijiu, rigorous sensory assessments were conducted by the researchers in a specialized Baijiu tasting room on seven randomly coded sauce-flavored Baijiu samples. During each assessment, these samples were poured into standard tasting cups, with each cup containing approximately 20 milliliters of liquor. The evaluation process encompassed multiple dimensions, including the appearance, aroma, taste, and overall style of the Baijiu. Each taster completed three rounds of tasting, ensuring that each round was completed within 50 minutes, with a 20-minute interval between rounds to ensure accuracy and reliability of the evaluation.

To ensure the professionalism and consistency of the evaluation, the research team followed the simple descriptive test procedures outlined in GB/T 10220-2012 "General Principles of Sensory Analysis Methods" and referred to the standard terminology in GB/T 33405-2016 "Terminology for Sensory Evaluation of Baijiu" to describe the characteristics of the samples. During the tasting process, the tasters evaluated the samples blindly, meaning they were unaware of the specific identity of each sample, to ensure objectivity in their assessments. Through multiple rounds of tasting and discussion, the research team determined the common sensory descriptive vocabulary for all samples, unified and standardized different descriptions, ultimately forming a comprehensive and accurate sensory evaluation for each sauce-flavored Baijiu.

2.5. Gas Chromatography Analysis Method

Gas chromatography was used to analyze flavor

compounds such as acids, alcohols, aldehydes, and esters.

(1) Preparation of Internal Standard: Transfer 1 ml of n-butyl acetate and dilute to volume in a 100 ml volumetric flask with 100% ethanol.

(2) The detection method was based on the measurement method in reference[28], using a capillary column: CP-Wax 57 CB (50 m×0.25 mm×0.2 μm);

Conditions: Carrier gases were N2, H2, and air, with flow rates of 1 mL/min, 45 mL/min, and 450 mL/min, respectively, set at a split ratio of 10:1. Injection volume: 1 μL.

Temperatures were set as follows: Injector temperature: 240 ℃; Column temperature: Initially at 35 ℃ for 6 min, then increased to 60 ℃ at a rate of 4 ℃/min, further increased to 110 ℃ at a rate of 6 ℃/min and held for 3 min, then increased to 205 ℃ at a rate of 6 ℃/min and held for 13 min.

Transfer 10 mL of the sample, add 100 μL of the 1% internal standard solution, mix well, and analyze. Each sample was analyzed in triplicate.

2.6. Data Analysis

Each experiment was repeated three times. Results are expressed as "mean ± standard deviation." Data were organized and statistically analyzed using SPSS 16.0 software, and multiple comparisons of the experimental results were performed using the Duncan method.

3. Results and Discussion

3.1. Results of Professional Sensory Evaluation

The sensory evaluation of seven sauce-flavored Baijiu samples was conducted, and the results are presented in Table 4. Upon describing the sensory characteristics of these seven sauce-flavored Baijiu samples, it was found that while they exhibited some differences and unique sensory quality attributes, they also shared common features: transparent appearance, prominent sauce aroma, and typical style[29].

Table 4. Sensory evaluation results of Jiangxiang baijiu

	Evaluation result
JJ1	The Baijiu is colorless and transparent, with no precipitation, suspension or impurities. Weak soy sauce aroma, with ethanol flavor, thin and weak taste in the mouth, short aftertaste, no obvious fragrance in empty glass. Slightly yellow and transparent, with prominent soy sauce flavor, elegant and delicate. Harmonized and soft body, long aftertaste, empty glass fragrance, typical style.
JJ2	The Baijiu is colorless and transparent, with no precipitation, suspension or impurities. The aroma of soy sauce is weak, with a bad aroma, sour and sweet in the mouth, no sense of hierarchy, short aftertaste, and short retention of aroma in the empty glass.
JJ3	The Baijiu is colorless and transparent, with no precipitation, suspension or impurities. The aroma of soy sauce is weak, slightly grain aroma, mixed taste, aftertaste is a little short, the empty glass retains the fragrance of rich and long-lasting.
JJ4	The Baijiu is colorless and transparent, with no precipitation, suspension or impurities. The aroma of soy sauce is weak, the aroma of aging is obvious, the mouth is soft, the aftertaste is clean and refreshing, and the aroma of empty glass is average.
JJ5	The Baijiu is colorless and transparent, with no precipitation, suspension or impurities. The aroma of soy sauce is still good, the mouth is mellow and sweet, with a sense of layers, the aftertaste is long, and the empty glass retains the fragrance for a long time.
JJ6	The Baijiu is colorless and transparent, with no precipitation, suspension or impurities. The aroma of soy sauce is prominent, the paste aroma is obvious, the mouth is clean and full, the aftertaste is long, and the empty glass retains the fragrance richly and persistently.
JJ7	The Baijiu is colorless and transparent, with no precipitation, suspension or impurities. The aroma of soy sauce is rich, and the aroma of aging is obvious, the mouth is full and comfortable, the aftertaste is long, and the empty glass retains a rich and lasting aroma.

It can be observed that these seven Sauce Flavor Baijiu samples exhibit their unique characteristics. Although produced by the same manufacturer, differences in production processes lead to significant variations in quality and style among these samples. For instance, JJ1, JJ2, and JJ3 demonstrate weak sauce aroma, which is attributed to their production process using the "chuansha" technique. JJ4 also exhibits a weak sauce aroma but is slightly better than JJ1, JJ2, and JJ3. However, JJ5 presents a moderate sauce aroma, weaker than JJ6 and JJ7. This is because JJ5 is a blend of two styles of Baijiu, "suisha" and "kunsha". Among these seven samples, JJ6 and JJ7 exhibit the most prominent sauce aroma. JJ7, typical of the "kunsha" style, has a rich sauce aroma with evident aged flavor. Besides differences in aroma, these seven samples also slightly vary in taste. JJ1, JJ2, and JJ3, produced using the "chuansha" technique, have a relatively thin mouthfeel upon entry, with JJ3 even having off-flavors. These three samples lack depth in layers and have a short aftertaste. JJ4, as a "suisha" style Baijiu, has a soft mouthfeel upon entry, a clean aftertaste, and moderate lingering aroma in an empty cup. JJ5, a blend of "suisha" and "kunsha" styles, has a sweet and layered mouthfeel upon entry, a long aftertaste, and a persistent lingering aroma in an empty cup. JJ6 and JJ7, typical of the "kunsha" style, have a clean and full mouthfeel upon entry, a long and lingering aftertaste, and a rich and lasting aroma in an empty cup[30].

3.2. Analysis of Flavor Compounds in Sauce Flavor Baijiu

Baijiu primarily consists of water and ethanol, accounting for about 98%, while the remaining 1% to 2% comprises trace components. However, it is these trace yet abundant flavor and taste compounds that determine the quality and style of Baijiu. These flavor compounds encompass esters, alcohols, aldehydes, acids, etc.

This study analyzes the content and proportion of flavor compounds in Sauce Flavor Baijiu, and the results are presented in Table 5.

As indicated by the flavor compound content results presented in Table 5, the Chuansha-style sauce aroma Baijiu samples (JJ1, JJ2, JJ3) exhibit relatively low concentrations of acetaldehyde, particularly JJ2 (101.12±8.48 mg/L), which may contribute to their less prominent aroma compared to other production techniques. The methanol concentration is moderate, but higher alcohols such as n-propanol and isoamyl alcohol are generally low, resulting in a relatively thin mouthfeel and weak layered flavors. The concentrations of key aroma components like ethyl acetate and ethyl lactate are also low, further compromising their aroma expression.

The Suisha-style sauce aroma Baijiu (JJ4) has a moderate acetaldehyde concentration (157.14±9.04 mg/L), contributing to its aroma. The methanol concentration is similar to that of Chuansha-style samples, at a medium level. Higher concentrations of isobutyl alcohol and isoamyl alcohol provide complexity and depth. The concentrations of ethyl

acetate and ethyl lactate are moderate, with ethyl lactate (1396.15±22.67 mg/L) being slightly higher, resulting in a smoother mouthfeel.

Table 5. Content of flavor substances in Sauce Flavor Baijiu with different processes

	Concentration (mg/L)						
Component Name	JJ1	JJ2	JJ3	JJ4	JJ5	JJ6	JJ7
Acetaldehyde	183.45±10.23	101.12±8.48	140.52±9.43	157.14±9.04	191.27±10.82	410.05±17.34	118.57±8.69
Methanol	53.51±6.72	59.89±6.73	85.51±7.72	59.92±6.80	108.76±8.85	178.12±9.95	112.26±8.53
n-Propanol	335.30±16.87	562.81±18.67	873.10±17.64	1030.63±19.15	421.49±17.36	1372.83±22.82	2461.27±36.56
Ethyl acetate	2040.44±33.16	1786.75±27.52	1766.61±27.05	1868.29±28.57	1449.63±25.24	2451.09±36.49	2073.91±30.28
sec-Butanol	——	38.54±4.26	44.53±5.18	60.44±6.96	17.01±2.15	49.51±5.56	76.31±6.67
Isobutanol	12.69±1.32	11.29±1.28	85.36±8.27	104.91±8.52	70.63±7.97	211.03±11.12	110.04±8.67
Acetal	271.53±13.84	167.37±7.14	245.48±13.34	274.65±13.96	289.78±10.56	707.39±17.68	202.72±11.85
n-Butanol	7.46±0.75	6.91±0.83	7.76±0.79	15.82±1.25	18.21±1.89	37.24±4.29	76.34±6.59
Isoamyl Alcohol	78.71±7.86	127.67±8.12	185.39±10.28	167.09±9.98	147.80±9.51	335.86±11.55	208.91±11.06
Ethyl Butyrate	95.92±8.47	44.53±5.77	37.66±4.53	51.03±5.83	37.72±5.47	60.81±6.02	45.68±5.83
n-Butyl Acetate	352.06±0.98	352.09±0.63	352.08±0.89	352.00±0.67	352.08±0.71	352.05±0.81	352.03±0.75
Ethyl Lactate	1002.61±19.40	1023.51±20.63	1285.72±22.19	1396.15±22.67	1508.36±24.69	1422.23±23.04	2056.47±34.08
Ethyl Valerate	75.72±7.33	17.25±2.07	23.70±2.25	7.58±0.51	——	35.86±3.93	——
Ethyl Caproate	——	23.30±2.54	27.72±2.46	36.22±4.05	18.15±1.98	44.41±4.74	——
Caproic Acid	——	——	——	——	——	——	51.62±5.08

The blended sauce aroma Baijiu of Suisha and Kunsha styles (JJ5) has medium to high concentrations of acetaldehyde and methanol, imparting certain aroma and complexity to the liquor. The higher alcohol concentrations are moderate, with a balanced ratio of isobutyl alcohol and isoamyl alcohol, offering layered flavors. The concentrations of ethyl acetate and ethyl lactate are also moderate, with a higher ethyl lactate concentration (1508.36±24.69 mg/L) enhancing the smoothness of the mouthfeel.

The Kunsha-style sauce aroma Baijiu samples (JJ6, JJ7) exhibit significantly higher acetaldehyde concentrations, especially JJ6 (410.05±17.34 mg/L), making their aroma more prominent and intense. The methanol concentration is also higher, but the overall flavor is acceptable. The higher alcohol concentrations are significantly higher than those of other production techniques, imparting complexity and fullness to the liquor. The concentrations of ethyl acetate and ethyl lactate are high, with JJ7 having the highest ethyl lactate concentration (2056.47±34.08 mg/L), conferring a smooth and long-lasting aftertaste.

Overall, different production techniques significantly impact the flavor of sauce aroma Baijiu. Chuansha-style sauce aroma Baijiu has low flavor compound concentrations and a thin mouthfeel. Suisha-style sauce aroma Baijiu offers some complexity and a smooth mouthfeel. The blended sauce aroma Baijiu of Suisha and Kunsha styles has balanced flavors. Kunsha-style sauce aroma Baijiu, with its high flavor compound concentrations, exhibits a unique, complex, and full flavor. These differences are not only reflected in the concentrations of individual flavor compounds but also in their interactions and balance, collectively shaping the unique flavor characteristics of sauce aroma Baijiu produced by different techniques. These findings provide important insights into the flavor formation mechanisms of sauce aroma Baijiu and inform process optimization.

4. Conclusion

This study delved into the impact of different production techniques on the sensory quality and flavor characteristics of sauce aroma Baijiu. Through systematic sensory evaluation and flavor compound analysis, significant differences among sauce aroma Baijiu produced by various techniques were revealed. The results indicate that sauce aroma Baijiu produced by different techniques exhibits distinct sensory qualities and flavor characteristics.

Specifically, Chuansha-style sauce aroma Baijiu (JJ1, JJ2, JJ3) has generally low flavor compound concentrations, particularly acetaldehyde, higher alcohols, and key aroma components like ethyl acetate and ethyl lactate, resulting in weaker aroma expression, a relatively thin mouthfeel, and weak layered flavors. In contrast, Suisha-style sauce aroma Baijiu (JJ4) shows elevated concentrations of acetaldehyde, isobutyl alcohol, and isoamyl alcohol, contributing to its aroma and mouthfeel complexity. The blended sauce aroma Baijiu of Suisha and Kunsha styles (JJ5) achieves a good balance between aroma and mouthfeel, with moderate concentrations of various flavor compounds, resulting in balanced flavor characteristics. Kunsha-style sauce aroma Baijiu (JJ6, JJ7) is notable for its high concentrations of acetaldehyde, higher alcohols, and aroma components like ethyl acetate and ethyl lactate, imparting a prominent aroma, full mouthfeel, and long-lasting aftertaste.

Furthermore, this study established a scientific data-based quality evaluation system for sauce aroma Baijiu. Through sensory evaluation, flavor compound analysis, and multivariate statistical methods, the sensory characteristics and flavor compound basis of sauce aroma Baijiu were systematically analyzed. This system enhances the objectivity and accuracy of sauce aroma Baijiu quality evaluation and provides scientific evidence and technical support for process optimization and quality improvement.

In summary, different production techniques significantly

influence the sensory quality and flavor characteristics of sauce aroma Baijiu. Variations in flavor compound concentrations and ratios among different techniques contribute to their unique flavor profiles. This study's findings not only enrich the research on the flavor chemistry of sauce aroma Baijiu but also provide important theoretical support and practical guidance for the development of the sauce aroma Baijiu industry.

5. Discussion

Firstly, sensory evaluation results indicate that sauce aroma Baijiu produced by different techniques exhibits significant differences in aroma, mouthfeel, and overall style. Chuansha-style sauce aroma Baijiu (JJ1, JJ2, JJ3), due to its relatively low acetaldehyde concentration, especially JJ2 with an acetaldehyde concentration of only 101.12±8.48 mg/L, exhibits weaker aroma, a thin mouthfeel, and a short aftertaste. In contrast, Suisha-style sauce aroma Baijiu (JJ4) and Kunsha-style sauce aroma Baijiu (JJ6, JJ7), with their higher acetaldehyde and higher alcohol content, exhibit more intense aroma and fuller mouthfeel with a longer aftertaste. Particularly, Kunsha-style sauce aroma Baijiu, with its rich content of higher alcohols and esters, achieves high levels of aroma and mouthfeel.

Flavor compound analysis further validates the sensory evaluation results. Chuansha-style sauce aroma Baijiu generally has low flavor compound concentrations, especially deficiencies in key aroma components like ethyl acetate and ethyl lactate, limiting its flavor richness. In contrast, Suisha-style and Kunsha-style sauce aroma Baijiu, with their advantages in flavor compound variety and content, exhibit unique flavor characteristics. Notably, Kunsha-style sauce aroma Baijiu, with its high concentrations of acetaldehyde, higher alcohols, and esters, collectively forms a rich and complex flavor profile.

Additionally, this study employed multivariate statistical methods to analyze flavor compound data, revealing the intrinsic correlations of flavor characteristics among sauce aroma Baijiu produced by different techniques through methods like Principal Component Analysis (PCA). The results indicate that differences in flavor compound concentrations and ratios among Chuansha, Suisha, Kunsha, and their blended techniques are the fundamental reasons for their distinct sensory qualities and flavor characteristics.

In conclusion, this study not only enriches the research on the flavor chemistry of sauce aroma Baijiu but also provides important theoretical evidence and technical support for quality control and process optimization of sauce aroma Baijiu. Through systematic sensory evaluation, flavor compound analysis, and multivariate statistical methods, we have revealed the differences in sensory quality and flavor characteristics among sauce aroma Baijiu produced by different techniques and established a scientific quality evaluation system. These findings are significant for promoting the sustained and healthy development of the sauce aroma Baijiu industry.

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