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Research Article

Research Progress on the Aromatic Components of Fen-flavor Liquor (*Baijiu*)

[1]Qi Zhang, [1]Jian-Gang Yang, [2]Zong-Hua Ao, [1]Jia-Xiu Guo, [1]Chang Su and [2]Cai-Hong Shen
[1]Bioengineering Institute, Sichuan University of Science and Engineering, Zigong, Sichuan 643000,
[2]Luzhoulaojiao Co., Ltd., Luzhou, Sichuan 646003, China

Abstract: Fen-flavor liquor is one of the three basic types of Chinese liquors and can be classified into *Daqu*, *Fuqu* and *Xiaoqu* light-flavor Chinese liquors based on the raw materials used as fermentation starter. The characteristic flavor and taste of Fen-flavor liquor is attributed to its different aromatic components. This study compares the production process and characteristics of *Daqu*, *Fuqu* and *Xiaoqu* Fen-flavor liquors. We review the current research status on aroma compounds and developmental trends in light-flavor Chinese liquors to provide a basis for further studies on the flavor compounds in different types of Chinese liquors.

Keywords: Fen-flavor Liquor, flavor compound, research progress

INTRODUCTION

Chinese liquor, a traditional distilled alcoholic beverage in China, is one of the six famous distilled spirits in the world. On the basis of the product flavor, Chinese liquors can be classified as strong-flavor (*Luzhou*-flavour), sauce-flavor (*Mao*-flavour), light-flavor (*Fen*-flavour), rice-flavor, medicine-flavor, miscellaneous-flavor, sesame-flavor, *Te*-flavor and *Chi*-flavor. While the first five types comprise the major flavors, the latter five are the minor flavors. In addition, there exist *Fuyu* and the *Laobaigan* flavors represented by *Jiugui* and *Hebei Hengshui laobaigan* liquors, respectively. Chinese liquors can also be classified as solid-state fermented, semisolid-state fermented and liquid-state fermented liquors based on their manufacturing techniques. Furthermore, the types of saccharifying agent and fermentation starter used lead to the production of *Daqu*, *Xiaoqu* and *Fuqu* types of liquors (Shen, 2014). Strong-flavor Chinese liquors are produced in mud pits using solid-state fermentation and back-slopping technique with mixed steaming and heating. The principle flavor compound is ethyl hexanoate supplemented with appropriate amounts of ethyl lactate, ethyl acetate and ethyl butyrate. On the other hand, sauce-flavor Chinese liquors are produced through solid-state fermentation in a stone pit with a mud bottom and mud seal using high-temperature *daqu*. The production process includes two rounds of feeding of high-temperature stacking, multiple fermentation and high-temperature collection. The characteristic sauce flavor is contributed by several agents such as 4-ethylguaiacol, pyrazine and heated aromas and furan as well as pyran. The characteristics of the rice-flavor Chinese liquors include the use of large stainless steel tank, semisolid-state fermentation, kettle distillation and fermentation period of 7 days. Ethyl lactate, ethyl acetate and appropriate amounts of β-phenylethanol constitute their principle flavor components. It is established that the amount of β-phenylethanol should be ≥30 mg/L for the alcohol content to be higher than the ester content. *Fen*-flavor Chinese liquors are characterized with the use of fresh mud pits for solid-state fermentation, mixed steaming and heating, "*laowuzhen*" back-sloping technique, storage in *jiuhai* ("alcohol sea," an enormous storage container in China) and a fermentation period of 12-14 or 28-30 days. Ethyl acetate is the principle flavor compound, while ethyl hexanoateacts as asecondary flavor compound in these liquors (Shen, 2014; Lai, 2005). Of these liquors, light-flavor Chinese liquors occupy an important place owing to their unique flavor as well as taste and have sparked increasing interest among the consumers. These are a large family of liquors and have many different derivative groups, which mainly include *Daqu*, *Fuqu* and *Xiaoqu* types. Fen-flavor Chinese liquor is one of the five major Chinese liquors and bears anelegant style, mellow and refreshing taste and fermentation techniques similar to those of internationally renowned distilled spirits such as brandy, whisky, rum, vodka and gin (Guo *et al*., 2012). At present, all popular international distilled liquors are elegant with a mild fragrant aroma. For instance, brandy has a crystal-clear transparent appearance, a unique fruity flavor of grapes,

Corresponding Author: Jian-Gang Yang, Bioengineering Institute, Sichuan University of Science and Engineering, Zigong, Sichuan 643000, China

a mellow, sweet, refreshing, penetrating, delicate taste and a rich smell. British gin is colorless and transparent, with a mild fragrant aroma and a refreshing mellow taste. Vodka is pure and colorless without any off-flavors. However, the light-flavor Chinese liquor exhibits a characteristic pure and mild flavor, gentle and sweet taste, harmonious aroma and a refreshing after-taste-characteristics similar to those of the internationally popular liquors; thus, it has gained increasing popularity among foreign customers.

The widespread use of gas chromatography in the mid-1960s has contributed to the study of flavor compounds that provide aroma to light-flavor Chinese liquors. Since then, the systematic and accurate use of sensory analysis has led to the detection of many genuine and important compounds. At present, there are over 7,000 types of identified flavor compounds (Fan and Xu, 2011). However, the aroma of Chinese liquor is very complex, attributed to thousands of compounds. Each of these compounds has a unique odor detection threshold and contributes differently to the overall aroma of the product. Thus, it has become important to identify flavor compounds with maximum contribution to the flavor of each Chinese liquor type. In this study, we compare production techniques and characteristics of *Daqu*, *Fuqu* and *Xiaoqu* light-flavor Chinese liquors. In addition, we review the current research status on aroma compounds and developmental trends in light-flavor Chinese liquors to provide a basis for further studies on the identification of flavor compounds and their formation mechanisms in Chinese liquors.

Comparison of production techniques and flavor characteristics of light-flavor Chinese liquors:

***Daqu* light-flavor Chinese liquor:** Light-flavor Chinese liquors are named after their pure and mild aroma. The *Daqu* light-flavor Chinese liquor is prepared using *Daqu* as a saccharifying and fermentation agent. The fen liquor of Xinghua village, Shanxi, is typical light-flavor Chinese liquor in China. It bears characteristics such as sweet, pure, natural, harmonious, mellow, soft and long-lasting smell as well as a refreshing pure after-taste. Under ideal conditions, the ratio of ethyl acetate and ethyl lactate (principle flavor compounds) in the final product is 55%:45%. Fen liquor holds a high reputation of being one of the famous liquors in China and is termed as "liquid gemstone." The ground water from the "*ancient wells"* and "*legendary springs"* in Xinghua village is used its brewing and high-quality barley and peas are used as raw materials for starters. Starters are inoculated with natural microorganisms. A traditional fermentation technique (a solid-state fermentation in underground vats) with two repeats (two rounds of addition of starter, fermentation and distillation) is used to process until purity. In other words, for every new batch, the raw materials are individually steamed for gelatinization and fermented and distilled twice. Fermentation is carried out for a period of 28 days. Jingxia Shi employed advanced Gas Chromatography-Olfactometry (GC-O) in combination with Gas Chromatography-Mass Spectrometry (GC-MS) for the quantitative analysis of trace components and flavor compounds in light-flavor Chinese liquor in China. This study identified 703 trace components, 100 flavor compounds and 31 important aromatic components, which include the characteristic flavor compounds of light-flavor Chinese liquors (Shi, 2009).

***Fuqu* light-flavor Chinese liquor:** *Fuqu* light-flavor Chinese liquor uses *Fuqu* as the saccharifying and fermentation agent. High-grade *Fuqu* Chinese liquor debuted in the 2nd National wine tasting convention in 1963 together with *Harbin Laobaigan* liquor, *Lingchuan* Chinese liquor and *Cangzhou* Chinese liquor and was given the title of national high-grade Chinese liquor, which placed *Fuqu* high quality Chinese liquor on the stage of Chinese alcoholic beverages (Shen, 2014). Beijing Red Star Erguotou liquor with a colorless transparent appearance is a typical representative of *Fuqu* light-flavor Chinese liquor. Ethyl acetate and ethyl lactate are the principle flavor compounds that contribute to its mild and elegant fragrance. In addition, it has a characteristic rich and sweet taste, long-lasting after-taste and clean tail. The *Fuqu* light-flavor Chinese liquor is produced using liquid glucoamylase as a saccharifying agent and liquor-making and flavor-producing yeasts as fermentation agents in a period of 7-21 days. The production process involves the utilization of large volume of residual fermented grains, clear steaming and heating and *laowuzhen* distillation technique. Yanhong Du *et al*. used immersion solid-phase microextraction and Liquid-Liquid Extraction (LLE) as sample pretreatment techniques in combination with GC-MS for qualitative analysis of flavor compounds from fresh distillates of the Red Star Erguotou liquor. They identified a total of 138 flavor compounds as below: 16 types of alcohols, 6 aldehydes, 16 carboxylic acids, 49 esters, 7 aromatic and phenolic compounds, 3 ketones and furans, 1 pyrazine, 6 acetals and 31 other compounds. This study provided a basis for further research on flavor compounds of Red Star Erguotou liquor (Du *et al*., 2010).

***Xiaoqu* light-flavor Chinese liquor:** *Xiaoqu* light-flavor Chinese liquor, also known as Chuanfa *Xiaoqu* Chinese liquor, is one of the major liquors in China and mainly distributed in Sichuan, Chongqing, Yunnan, Guizhou, etc (Zeng, 2006; Wu *et al*., 2014). Its unique characteristics include colorless and transparent appearance, mellow and elegant taste, soft-wine body,

Table 1: Production process parameters for three types of Fen-flavor liquor

Type item	*Daqu* light-flavor Chinese liquor	*Fuqu* light-flavor Chinese liquor
Main raw materials	Sorghum	Sorghum, barley, peas, etc.
Processing of raw materials	Crushing	Crushing
Additional materials	Bran	Husk
Saccharifying and fermentation starters	*Daqu*	*Fuqu*
Fermentation vessel	Ceramic vat	Cement pit with or without ceramic tiles
Characteristics of fermentation method	Clear steaming and clear dregs, vat fermentation, steaming with two repeats	Mostly adopt clear steaming and heating, use of residual fermented grains for fermentation
Fermentation period	Traditional period of 21 days, can be extended to 28 days to increase flavors, and even longer in specific cases	Typically around 7-21 days, with more than 30 days for special flavor liquors
Distillation	Two rounds of distillation and fermentation for "dazha" and "erzha"	Slow steaming and high temperature liquor collection
Characteristic technique	Ceramic vat fermentation	Addition of distiller's yeast for fermentation
Type item	*Xiaoqu* light-flavor Chinese liquor	
Main raw materials	Sorghum, maize, wheat, barley,rice grains, etc.	
Processing of raw materials	Whole grain (no crushing required)	
Additional materials	Husk	
Saccharifying and fermentation starters	*Xiaoqu*	
Fermentation vessel	Cement pit with or without ceramic tiles	
Characteristics of fermentation method	Initial culture of microbes, followed by the addition of dregs for fixed-temperature fermentation	
Fermentation period	1 day for yeast culture, typically 7 days for fermentation, which can be extended by a few more days to increase the aroma	
Distillation	Ends are sealed and liquor is distilled out	
Characteristic technique	Box culture	

sweet and refreshing after-taste, purity, which are different from those of the mildly fragrant *Daqu* and *Fuqu* Chinese liquors. These characteristics are attributed to the elegant "residual fragrance" of *Xiaoqu* Chinese liquor. The production process is simple, cost-effective and involves the use of whole grains as raw materials, pure *Rhizopus* and yeast as saccharifying and fermentation agents and small amounts of *qu* (molded cereals). The fermentation process typically lasts for around 7 days and results in high liquor yield (Wu *et al*., 2014; Wen and Xiang, 2011; Wang *et al*., 2011a).

Comparison of production processes of the three types of light-flavor Chinese liquors: As evident from Table 1, production processes of the three types of light-flavor Chinese liquors show differences in parameters such as saccharifying and fermentation agents, fermentation period and fermentation method. While all three processes use sorghum as the main ingredient, *Fuqu* and *Xiaoqu* liquors include a variety of additional ingredients. In addition, the fermentation of *Daqu* light-flavor Chinese liquor carried out in a ceramic vat is different from those of *Fuqu* and *Xiaoqu* of Chinese liquors. One advantage of the production technique for *Xiaoqu* liquor is its short production time (7 days) as compared to other liquors.

The differences in these production techniques result in different aroma components of Chinese liquors, thereby giving a characteristic aroma to every liquor type. The types and functions of aroma components are considered as key factors affecting the quality of Chinese liquor flavor (Ye *et al*., 2008).

Report on the aromatic components of light-flavor Chinese liquor: Today, the research on the aromatic components of light-flavor Chinese liquor has entered a new phase. Ethyl acetate is reported to be the principle aromatic component in light-flavor Chinese liquor and contributes to more than 50% of the total ester content. Ethyl acetate and ethyl lactate contribute to 96.5% of total ester content and together determine the main flavor characteristics. Recent studies have thrown light on the important characteristics of typical aromatic components of *Daqu*, *Fuqu* and *Xiaoqu* light-flavor Chinese liquors. Below is the summary and analyses of these studies.

***Daqu* light-flavor Chinese liquor:** In 2009, Jingxia Shi analyzed and detected 100 types of flavor compounds in light-flavor Fen liquor using GC-O combined with GC-MS. Thirty-one of these compounds were identified as important aromatic components. Following eight key aromatic compounds were identified with Odor Analysis Value (OAV): ethyl octanoate, β-damascenone, ethyl hexanoate, acetal, ethyl acetate, ethyl 2-methylbutyrate, ethyl 3-phenylpropanoate and 3-methylbutyl acetate. In addition, this study identified a novelaromatic compound, β-damascenone, exclusively found in *Daqu* light-flavor Chinese liquor (Shi, 2009). In 2012, Junhua Guo *et al.* used LLE for the isolation of flavor compounds from different runs of fermented grains of fresh distillates and analyzed these flavor compounds using GC-O and GC-MS. The results showed that aromatic compounds and esters were important flavor components in fresh distillates of light-

Table 2: Report on the aromatic components of the three types of Fen-flavor liquor

Item type	Identified flavor components	Method used
Daqu light-flavor Chinese liquor	Fen liquor, 99 types (Ding, 2008)	GC-O combined with GC-MS
	Fen liquor, 100 types (Shi, 2009)	GC-O combined with GC-MS
	Fen liquor, Baofeng liquor, Qingke liquor, 66 types (Cheng *et al*., 2006)	GC-O combined with MS
Fuqu light-flavor Chinese liquor	Fresh distillates of Erguotou liquor, 70 types (Liao *et al*., 2014)	LLE, SDE, HS-SPME combined with GC-MS
	Niulanshanerguotou, 92 types (Wang *et al*., 2008)	LLE,GC-O combined with GC-MS
Xiaoqu light-flavor Chinese liquor	Sichuan-type Xiaoqu Chinese liquor (Yang *et al*., 2015)	HS-SPME combined with GC-MS
Item type	Characteristic (key) aromatic components	
Daqu light-flavor Chinese liquor	Ethyl octanoate,ethyl acetate, phenylacetaldehyde, 4-ethylguaiacol, 3-methylbutanol, 2-methylpropanol, 1-octanol,ethyl phenylacetate, 2-phenethyl acetate and 2-phenylethanol	
	Ethyl octanoate, β-damascenone, ethyl hexanoate, acetal, ethyl acetate, ethyl 2-methylbutyrate, ethyl 3-phenylpropanoate and 3-methylbutyl acetate	
	β-damascenone andethyl acetate	
Fuqu light-flavor Chinese liquor	Isopentanol, ethyl lactate, diethyl succinate, ethyl acetate, 1-hexanol, octanoic acid, ethyl nonanoate and isopentyl hexanoate	
	3-methylbutanol and 25 other types	
Xiaoqu light-flavor Chinese liquor	Ethyl acetate, isopentyl esters, ethyl octanoate, ethyl laurate and ethyl decanoate	

flavor Chinese liquors (Guo *et al*., 2012). In 2014, Gao *et al*. (2014) showed that β-damascenone and ethyl acetate are the key aromatic components in Fen liquor and demonstrated the function of esters such as ethyl lactate, geosmin, ethanoic acid and 2-butanol in *Daqu* light-flavor Chinese liquor.

***Fuqu* light-flavor Chinese liquor:** In 2011, Yong Wang *et al*. used LLE for the extraction ofaromatic compounds from *Niulanshan erguotou* Chinese liquor and employed GC-O and GC-MS for their separation and identification. The following 25 flavor components exhibited highest contribution to the flavor of the product: 3-methylbutanol, butanoic acid, 3-methylbutanoic acid, ethyl hexanoate, 3-methyl-1-butanol, ethyl acetate (3-methyl-1-butanol and ethyl acetateas the main compounds extracted using solid-phase microextraction [SPME]), dimethyl trisulfide, vanillin, phenylacetaldehyde, ethyl phenylacetate, phenylacetic acid, 2-acetyl-5-methyl furan, trimethylpyrazine, ethyl octanoate, 2-methylpropyl acetate, ethyl pentanoate, ethyl 2-hydroxyhexanoate, diethyl succinate, octanoic acid, 2-methylpropanoic acid, pentanoic acid, 2-methylpropanol, heptanol, 4-ethylguaiacol, phenylethylacetate, phenylpropanoic acid and tetramethyl pyrazine (Wang *et al*., 2011b). In 2012, Chunxia Yang *et al*. used LLE and SPME combined with GC-MS for the identification of flavor components of *Niulanshan erguotou* light-flavor Chinese liquor. Ethyl 2-hydroxypropanoate, 3-methyl-1-butanol, ethyl hexadecanoate, ethyl linoleate and ethyl oleate were determined as the main flavor components; and ethanoic acid and ethyl hexanoate (Yang *et al*., 2012). In 2014, Yonghong Liao *et al*. used LLE, Simultaneous Distillation Extraction (SDE) and Headspace (HS)-SPME combined with GC-MS for the detection of flavor components of *Niulanshan erguotou* liquor. Retention index method was used to verify the results, while threshold conversion method was used to obtain an OAV for each compound. Compounds with high OAV were confirmed to be the key aromatic components. This study showed eight key aromatic compounds as isopentanol, ethyl lactate, diethyl succinate, ethyl acetate, 1-hexanol, octanoic acid, ethyl nonanoate and isopentyl hexanoate (Liao *et al*., 2014).

***Xiaoqu* light-flavor Chinese liquor:** In 2015, Jiangang Yang *et al*. used HS-SPME combined with GC-MS for the analysis of key volatile components in Sichuan-type *Xiaoqu* Chinese liquor. The study identified 64 volatile components from four Sichuan-type *Xiaoqu* Chinese liquors from different areas. Of these, 29, 31, 44 and 45 components were detected in Jiangjin, Yongchuan, Kaijiang and Zigong liquors, respectively. There were 15 common compounds in all four liquors, including ethyl acetate, 1-propanol, isopentanol and ethyl decanoate. Principal component analysis showed that 15 compounds, including 1-propanol, isopentanol, ethyl acetate, isopentyl acetate, ethyl decanoate and ethyl lactate, exhibited highest contribution to the flavor. Quantitative results revealed the content of ethyl acetate, ethyl lactate, 1-propanol, isobutanol and isopentanol to be 0.4170-2.0880, 0.1115-0.2809, 0.5416-0.9729, 0.3327-0.6371 and 0.7721-1.1701g/L, respectively (Yang *et al*., 2015). In 2016, Hechuan Wu *et al*. used HS-SPME combined with GC-MS for the detection of flavor components from Sichuan-type *Xiaoqu* Chinese liquor and optimized the factors that may affect the results of HS-SPME. The study showed that the best extraction efficiency was achieved using the following parameters: 20% volume, 45% liquid

volume, 0.1 g/mL sodium chloride (NaCl), 45°C equilibration temperature, 30-min equilibration and 50-min extraction. Using these parameters, 45 flavor components were detected in Sichuan-type *Xiaoqu* Chinese liquor, including 29 types of esters, 5 types of alcohols and 1 aldehyde (Wu *et al*., 2016).

Current literature on light-flavor Chinese liquors revealed that Chinese liquors of same flavor exhibit similar key flavor compounds. However, Chinese liquors of same flavor type made using same techniques but different raw materials exhibit different constituent flavor compounds. Similar results were observed with variations in techniques. Thus, different techniques of liquor production can show complementarity during quantitative analysis (Table 2).

Outlook for light-flavor Chinese liquor development: Light-flavor Chinese liquor is popular among international consumers for its refreshing, pleasant, pure and elegant taste. The taste and features of this liquor are comparable to those of whisky, brandy, vodka and other trending international liquors. The traditional brewing technique has endowed light-flavor Chinese liquors with an international taste (Su, 2008). In 2004, the national revenue of light-flavor Chinese liquors was around 6 billion RMB and occupied about 7% of the national market. In 2008, light-flavor Chinese liquors occupied about 21% of the national Chinese liquor production. In 2009, Fen liquor had 3.8 billion sales, while sales of *Hengshui laobaigan*, *red sta*r and *Niulanshan* liquors exceeded 1.8 billion. In 2010, the sales of Chongqing light-flavor Chinese liquors occupied about 40% of market share, while those of Henan light-flavor Chinese liquors occupied around 15% of the market share. However, there are some short comings in the taste of the light-flavor Chinese liquor. It is refreshing, pure, natural and comfortable, but neither bears the soft taste of strong-flavor Chinese liquor nor the delicate taste of sauce-flavor Chinese liquor (Zhang and Zhou, 2010). The Inner Mongolia Camel Wine Business Company Limited not only inherits and develops the traditional brewing technique of light-flavor Chinese liquor but also carries out innovation and enhancements in the process testing on the quality of light-flavor Chinese liquors. This helps them produce different styles and tastes of Chinese liquors to satisfy the fashion, demand and health needs of consumers.

Light-flavor Chinese liquor has a long brewing history, which provides an overall understanding of the material basis of flavor compounds and flavor characteristics. Optimization of production techniques to strengthen the main flavor compounds and increase productivity of high-grade liquor may open new avenues for light-flavor Chinese liquors. The managing director and the general manager of Baofeng Wine Business Limited Company, Mr. Ruofei Wang, felt that the light-flavor Chinese liquor is the Chinese liquor that can best connect with the world. A century ago, light-flavor Chinese liquors were enthusiastically sought after at the Panama-Pacific International Exposition, highlighting its high recognition among the international consumers. Kefei Wang described the flavor of vodka in domestic publications as follows: “extracts of birch coal in liquor are the main source of vodka flavor. The so-called vodka flavor mainly refers to the mild fragrance from birch. Genuine vodka has no taste. The main flavor in Vodka is contributed by the aroma and taste of ethanol” (Wang, 2008; Yan, 1985; Qing, 1987; Zhang, 1995). Light-flavor Chinese liquors have their own characteristic taste, which is in line with the developing international trends of light-tasting food stuffs. Hence, the quality of light-flavor Chinese liquors can be improved by increasing the length of the after-taste. In short, the flavor characteristics of light-flavor Chinese liquors determine its international flavor requirements. In addition, different characteristics determine the enormous international and mechanization potential of light-flavor Chinese liquors. At present, light-flavor Chinese liquors still face some problems in the international market, necessitating improvements in stabilization of product quality, promotion of traditional techniques and long cultural history of liquors and marketing tactics.

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