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Review article

Baijiu (白酒), Chinese liquor: History, classification and manufactureXiao-Wei Zheng^a, Bei-Zhong Han^{b,*}^a Biotechnology Center, Nutrition & Health Research Institute, COFCO Corporation, Beijing, China^b College of Food Science and Nutritional Engineering, China Agricultural University, Beijing, China

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ABSTRACT

Baijiu (白酒) is a traditional fermented alcoholic drink originating in China, which is typically obtained by natural fermentation. It has a high reputation and constitutes an important part of Chinese dietary profile. The production of *baijiu* involves five major steps, materials preparation, *daqu* (大曲) making, alcoholic fermentation, distillation, and aging. There is a range of *baijiu* with different flavors and corresponding names. *Baijiu* can be categorized according to the production techniques (solid state and semi-solid state), types of starter [*daqu*, *xiaoqu* (小曲), and *fuqu* (麸曲)] and product flavor (strong, light, sauce, etc.). different types of *baijiu* have their *home microbiota* and flavor because of their distinct production techniques. In this review, we discuss the critical steps and the microorganisms involved in the production of different types of *baijiu*. Although *baijiu* contains alcohol, it has been proven that it plays a significant role in the health and quality of peoples' lives.

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1. Introduction

Chinese traditional fermentation techniques have benefited Chinese people for centuries. Traditional fermented products have improved the daily diet habit of Chinese people and have also enriched the catering culture in the world. Chinese fermented products primarily include staples, alcoholic drinks, condiments, and adjuncts to staples. They constitute a major part of the Chinese national food industry, valued at approximately 278 billion RMB annually [1]. *Baijiu* (白酒), Chinese liquor, has been regarded as the backbone of fermented products by Chinese people, because its production increased quickly and currently exceeds 12 million metric tons annually [2]. On average, each Chinese individual consumed *baijiu* at 9.43 L/y in 2013, which is almost equal to the maximum drinking volume of alcoholic drink by an American individual (8.2 L/year) [3].

Baijiu, written in hieroglyphics as a Chinese word, was derived from the words *bai* (白, transparent) and *jiu* [dju] (酒, alcoholic drink). *baijiu* is also known as *samshu*, *baigan* (白干), or *shaojiu* (烧酒, fired liquor), which is obtained by complex fermentation processes using natural mixed culture starters followed by distillation. *Baijiu* is a type of Chinese traditional distilled liquor and regarded as

one of the most famous distilled liquors in the world, together with brandy, gin, rum, vodka, and whiskey. As a product, it is not only an important commodity but also has a very close connection with social and economic activities. *Baijiu* has enriched living standard connotations of Chinese people and it was often given as a present or during important events.

The manufacture of *baijiu* began at least before the 2nd century BCE [4]. The *Ben-Cao-Gang-Mu* (本草纲目, *Chinese Materia Medica*), compiled by Li Shi-Zhen (李时珍) in 1597, indicates that solid-state fermentation (SSF) combined with distillation was invented during the era of the Yuan dynasty [5]. However, it is difficult for researchers to describe exactly when *baijiu* was invented. It is known that some of the early distillation appliances were closely linked to *baijiu* manufacture. An historical record mentions that the earliest distillation tools (distillation pan) appeared during the era of the Song dynasty [4]. The *Song-Shi* (宋史), authored by TuoTuo (脱脱) in 982 CE, described a method using wheat, barley, sticky rice, etc. to produce a distilled liquor, which is the exact approach for *baijiu* production used today.

Based on the development perspective of the historical and cultural heritage, *baijiu* can be used for a long time because of its good taste and healthy aspects. *Baijiu*, a special series of distilled liquors, was normally made from sorghum or a mixture of barley, corn, rice, wheat, and sorghum, containing abundant volatile components such as esters and organic acids [6]. These nonalcoholic components might participate in the prevention of cardiovascular diseases [7]. It has been reported that moderate

* Corresponding author. College of Food Science & Nutritional Engineering, China Agricultural University, No. 17 Qinghua East Road, Beijing 100083, China.

E-mail address: hbz@cau.edu.cn (B.-Z. Han).

consumption of *baijiu* could reduce uric acid concentration in serum and the risk of Alzheimer's disease [3]. It could improve serum lipid profiles in young people and decrease platelet aggregation and endothelial adhesion molecules to protect against the risk of cardiovascular diseases [5]. Therefore, Chinese people have regarded *baijiu* as a healthy product for a very long time and have recommended its consumption in small volumes every day.

2. Classification of *baijiu*

Hundreds of different types of *baijiu* are produced by various processes in different regions of China. They can be distinguished based on the manufacturing techniques, fermentation starters, and product flavors, as outlined below.

2.1. Manufacturing techniques

2.1.1. SSF *baijiu* (固态发酵白酒)

SSF is a process in which microbial cultures are grown on a solid matrix in the absence of a liquid (aqueous) phase [8]. This method has been commonly used for most of the well-known *baijiu* production techniques, and it has a long history and has been passed on through several generations. This type of *baijiu* is typically produced from grains such as sorghum, wheat, rice, glutinous rice, and maize by a complex SSF process, which consists of: (1) material preparation; (2) *daqu* making; (3) SSF; (4) solid-state distillation; and (5) aging [8]. This technique results in fermented materials containing approximately 60% water [8]. It can produce components with different flavors, depending on the different fermentation processes and operation conditions. Therefore, SSF is regarded as a method that could produce the maximal types of *baijiu*, with each product having different flavor and characteristics.

2.1.2. Semi-SSF *baijiu* (半固态发酵白酒)

Semi-SSF *baijiu* is represented by *guilinsanhua-jiu* (桂林三花酒) and *quanzhouxiangshan-jiu* (全州湘山酒). The fermentation process is operated under semi-solid state [9].

2.1.3. Liquid-state fermented *baijiu* (液态发酵白酒)

Liquid-state fermented *baijiu* is represented by *hongxing erguotou-jiu* (红星二锅头酒). All the production processes include saccharification, fermentation, and distillation performed under liquid state [10].

2.2. Fermentation starters

According to the starters used, three different types of *baijiu* can be distinguished [5], which are as follows:

- (a) *Baijiu* produced using *daqu* as the starter is represented by four most famous *baijiu*: (*moutai-jiu* 茅台酒, *wuliangye-jiu* 五粮液酒, *fen-jiu* 汾酒 and *luzhoulaojiao-jiu* 泸州老窖酒). *Daqu* is a type of grain, *qu* (曲), which is made from raw wheat, barley, and/or peas [11]. The wetted materials are transferred to a molding press and shaped as a brick, each weighing approximately 1.5 kg to 4.5 kg [12], with either a flat surface or one side in a convex shape. Because of its big size, it is therefore named as *daqu* (big starter). In general, four categories of microorganisms (bacteria, yeast, filamentous fungi, and actinomycetes) are found in *daqu*. They provide different enzymes and flavor precursors for the production of *baijiu*. *Baijiu* produced using *daqu* is enriched in flavors, with a long fermentation time and low alcohol production.
- (b) *Baijiu* produced using *xiaoqu* (小曲) as the starter is represented by *guilinsanhua-jiu* (桂林三花酒) and *liuyanghe-jiu* (浏

阳河酒) [13]. Compared to *daqu*, *xiaoqu* is a small starter, which is made from rice or rice bran [13]. Unlike *daqu*, only very a few types of microorganism are present in *xiaoqu*, including *Rhizopus*, *Mucor*, lactic acid bacteria, and yeasts. These microorganisms are primarily good fermentation performers; therefore, a small quantity of the starter and short fermentation period are used in the production of this type of *baijiu*. However, due to a few types of microorganism involved, *baijiu* produced using *xiaoqu* contains less flavor than that produced using *daqu*.

- (c) *Baijiu* produced using *fuqu* (麴曲) as the starter is represented by *erguotou-jiu* (二锅头酒) [14]. *Fuqu* is different from the other two starters and is made from bran and contains only pure culture of *Aspergillus* [14,15]. *Aspergillus* is a well-known starch degrader and can convert starch into fermentable sugars. Using *fuqu* as the starter, the produced *baijiu* has characteristics of light flavor and high liquor production.

2.3. Flavor of *baijiu*

Based on their flavor, *baijiu* can be divided into three major and nine minor categories (Fig. 1).

- (a) Sauce-flavor *baijiu* (酱香型白酒), such as *moutai-jiu* (茅台酒) and *lang-jiu* (郎酒), which provides a flavor resembling soy sauce, full-body and a long-lasting aroma. The major representative aroma compounds are phenolic compounds, primarily tetramethyl pyrazine (3,000–5,000 mg/L) and syringic acid, along with small quantities of amino acids, acids, and esters [16].
- (b) Strong-flavor *baijiu* such as *luzhoulaojiao-jiu* and *wuliangye-jiu*, which have the characteristics of fragrant flavor, soft mouthfeel, and endless aftertaste. The representative aroma compounds are predominantly ethyl hexanoate in harmonious balance with ethyl lactate, ethyl acetate, and ethyl butanoate [17].
- (c) Light-flavor *baijiu* (清香型白酒) such as *fen-jiu* (汾酒) and *erguotou-jiu*, which gives a pure and mild flavor, mellow sweetness and refreshing aftertaste. The major aroma compounds are ethyl acetate in balance with considerable levels of ethyl lactate [18].

The characteristics of these three flavor types are very typical and representative, and they comprise approximately 60% to 70% of *baijiu* in China. The production techniques for these three types of *baijiu* are standardized and stereotyped. In addition to these three types, some *baijiu* such as *baiyunbian-jiu* (白云边酒), *dong-jiu* (董酒) and *site-jiu* (四特酒), with a specific flavor and aroma characteristics are also produced using different techniques. They do not belong to the first three categories, and therefore nine additional flavors were established, which are described as follows (Fig. 1).

- (d) Miscellaneous-flavor *baijiu* (兼香型白酒) such as *baiyunbian-jiu* (白云边酒) has sensory characteristics ranging between those of sauce-flavor and strong-flavor *baijiu*. The representative aroma compounds in miscellaneous-flavor *baijiu* are heptanoic acid, ethyl heptanoate, isoamyl acetate, 2-octanone, isobutyric acid, and butyric acid.
- (e) *Feng*-flavor *baijiu* (凤香型白酒) such as *xifeng-jiu* (西凤酒) is characterized by sweet entrance and elegant aftertaste. The representative aroma compounds in *Feng*-flavor *baijiu* (凤香型白酒) are primarily ethyl acetate in balance with ethyl caproate [19].

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