Beverages: Asian Alcoholic Beverages

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Topic Highlights

- Many traditional alcoholic beverages are made in Asia by fungal fermentation of cereal grains.
- The best known rice wine is Japanese *saké*, which requires both *Aspergillus* and yeast fermentation.
- China has a diversity of sorghum-based distilled liquors, usually produced in batches by complex traditional processes.
- Understanding the traditional processes is the first step toward modernizing and adapting them for uniform high-throughput continuous production systems.

Learning Objectives

- To understand the product diversity and characteristics of Chinese and Japanese grain-based alcoholic beverages produced from fungal fermentation.
- To understand the roles of fungal starter culture and yeast fermentation during processing.
- To develop an insight into the complexities of adapting traditional production methods for large-scale modernized processing.

For many centuries, China and other East Asian nations have used a mold-based system for the production of alcohol from grains. This mold-based system has also been adapted to the production of other fermented products such as soy sauce. The foundation of the system is 'koji' (Japan), or 'jiuqu' (China). Grain is prepared and mold allowed to grow on it. The mold enzymes include α-amylase, gluco-amylase, as well as proteases. To produce rice wines such as 'saké' and Chinese rice wines, the molded grains are mixed with rice, and in a complex process the rice is converted to an alcoholic beverage. The distilled sorghum liquors depend on a semisolid fermentation followed by steam distillation. This is done up to 8 times with the same batch of sorghum with 'daqu' being added after each distillation.

Introduction

Yeasts can only produce alcohol from soluble monosaccharides and disaccharides, most commonly from glucose and maltose. Two sources of these sugars are fruit juices and starch, but the starch is insoluble and the sugars are in polymeric form and so generally unavailable to yeasts. In the West, this unavailability problem was solved by using sprouted barley to release enzymes that breakdown the insoluble starch in the grain to sugars for yeast growth. However, in China, after an attempt ~3000 years ago to use sprouting grain to brew 'Li' from 'Nie' in a process similar to beer brewing, the idea was dropped in favor of a microbial-based system in which 'Jiu' was brewed with 'Qu' Modern beer making was only introduced to China in 1900 at Harbin by Russians. The ancient Chinese system depends on growing mold on grain, essentially a solid-state fermentation for enzyme production, mixing the molded grain with cooked grain and water, then soaking it in water to allow the enzymes from the mold to breakdown the starch, followed by a yeast fermentation to produce alcohol. Rice wine or Japanese saké are the modern descendents of this technological innovation.

The molded cereal-based system starts with wet grain, cooked or uncooked, so that molds grow on the grain to produce carbohydrate degrading enzymes. In Japan, this molded product is called koji, in China it is qu or jiuqu, in Korea it is 'nuruk' (or 'nuluk'). In Southeast Asian countries, a similar powdered-rice product is made and they go by the names 'bubod,' 'ragi,' 'lakpaeng,' 'men,' and 'mochikouji,' but rice is not necessarily the source of sugar. In the Philippines, the wet form of koji is called 'binubudan' and sugar cane juice is fermented. Koji is used to produce a variety of foods, apart from alcoholic beverages, throughout east Asia. This microbial-based system of alcohol production has a long history, dating back to the Xia Dynasty, ~4000 years ago, but archeological artifacts associated with the technology have been dated to over 5000 years ago. Jiuqu has been specifically mentioned in Chinese literature dating from the Zhou Dynasty (770–221 bc). As with beer in the West, for centuries in China, and even now, some alcoholic beverages are thought beneficial to health.

In China, this mold-based system is used to make grain-based distilled liquors and wines, e.g., from rice, corn, millet, and sorghum. The Japanese have developed saké-brewing systems based on the scientific study of the organisms and processes while Chinese systems tend to be more traditional and far more complex.

Saké Brewing

The Japanese rice wine production began ~300 BC and today there are ~10 000 brands of saké produced in ~2000 factories. The Japanese have developed pure fungal and yeast culture based systems for rice wine production as opposed to the traditional rice wine making systems mostly used in China. Saké is classified according to the degree of polishing of the rice used to make the wine (Table 1). Rice grain weight reduction is from 25–35%. Generally, 'ginjo saké' is made with highly polished rice while 'honjozo saké' is made with rice not polished below 60%. Less highly polished rice results in a higher level of inosinic acid that is responsible for the characteristic flavor of saké.

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Table 1 Types of saké are based on the Seimaibuai classification that relies on the percentage of original rice left after the rice has been polished. The lesser the percentage of original rice, the lighter and more delicate is the flavor of the saké.

Type of saké	*Seimaibuai classification (% of rice left after polishing)*	*Comment*
Junmai dai ginjo	50	Highest grade of saké, light dry type
Junmai ginjo	60	Sweeter, heavier than above
Tokubetsu junmai	60	'Special Junmai,' a marketing product
Junmai	70	Means 'pure saké,' no added alcohol, with heavier, fuller flavor

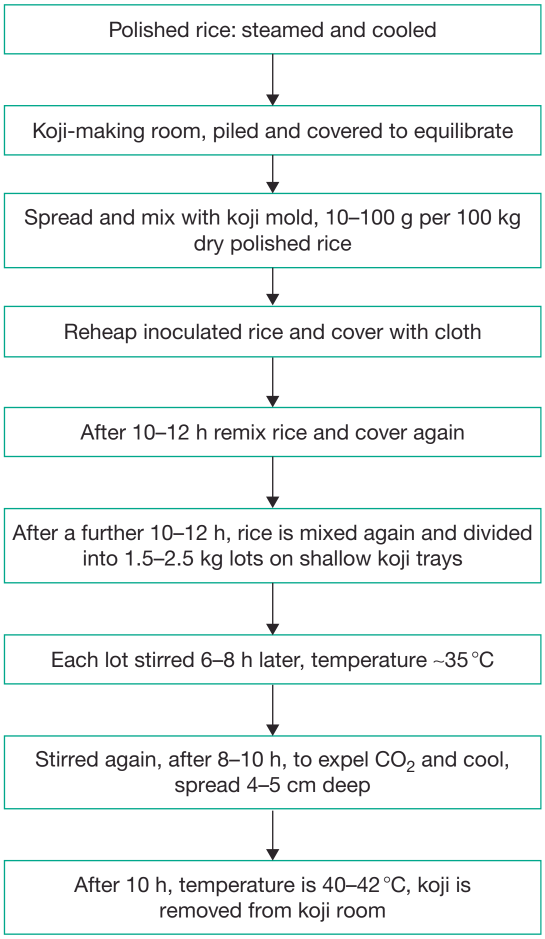

Figure 1 Koji production for saké manufacturing is an intensive process designed to maximize enzyme production.

Koji Production for Saké

Brewers favor large rice grains with soft kernels so that water uptake is rapid and mold mycelia can penetrate the kernels more easily (Figure 1). The mineral content of the water influences saké quality, iron levels must be low and potassium, phosphorus, and magnesium are required for mold growth, and calcium and chlorine improve fungal amylase extraction. The pH should be neutral to alkaline, of medium hardness (German scale 3–7) and highly chlorinated.

After washing off loose bran, the grains are steeped to take up water equal to 25–30% of the milled rice weight. The drained, steeped rice is then steamed in shallow open vessels for 30 min to 1 h, in batch systems, for a shorter period in continuous systems, so that the weight of the grains increase a further 8–12%. The rice is then cooled to 34–36 °C and transferred into the koji-making room where temperature and relative humidity can be controlled, and piled on an insulated bed and covered with cloth to allow equilibration with the room. The grains are then spread evenly and inoculated with 'tane-koji,' a seed culture of *Aspergillus oryzae* that has been grown for up to 6 days to maximize sporulation. It is inoculated at 10–100 g per 100 kg of polished rice, reheaped and covered with a cloth. The temperature rises as the fungus grows so the inoculated rice must be manipulated and mixed to control temperature.

The way the mold mycelia grow through the resulting molded grain influences the quality of the saké produced. If mold growth is confined to the outer layers of the grains, excessive breakdown of grain protein reduces saké quality. The fungus produces ~50 kinds of enzymes including proteases and amylases. Of particular importance are α-amylase (amylo-1,4-dextrinase) and *S*-amylase (amyloglucosidase), the former breaks down the starch molecules to smaller fragments to decrease viscosity, the latter removes glucose units.

Moto Production

In effect, this is the beginning of the brewing process because ingredients are added to the 'moto,' after it has been made, to make the saké. In moto production, yeast is prepared by a complex process that is, however, simpler than traditional methods. Water (200 l), rice-koji (60 kg), and steamed rice (120 kg) are mixed and held at 13–14 °C for 3–4 days with occasional stirring. The temperature drops to ~7–8 °C. During this stage, the koji enzymes begin the breakdown of the starch in the rice, and some wild bacteria and yeasts begin growing in the mix. However, lactic acid bacteria (*Leuconostoc mesenteroides* var. *saké* and *Lactobacillus saké*) begin growing and lower the pH. These acid conditions, along with the high levels of sugars, eventually kill off these organisms. The temperature rises to 15 °C and by ~15 days a pure culture of saké yeast, a strain of *Saccharomyces cerevisiae* but with some unique characteristics (Table 2), is added to give a population of $\sim 10^5$–10^6 g^{-1} that rises to $\sim 10^8$ g^{-1} as temperature also rises to 20–23 °C. A variation on this system is to add lactic acid to the moto mix to bring the pH down to 3.6–3.8 to prevent the wild microbial activity but the saké yeast must be added soon after. The characteristics of the water phase at yeast inoculation are: specific gravity, 1.124–1.128; reducing sugar, 26–28%; amino acid as glycine, 0.5–0.8%; total acid as lactic acid, 0.3–0.4%. Traditionally, it took 25–30 days to produce suitable moto.

Rice Wine Production

The wine-making process is basically a batch-fed system, the fermentation process is begun and further raw materials are fed

Table 2 Some cultural characteristics that distinguish saké yeast and *S. cerevisiae*

	Response	
Characteristic	*Saké yeast*	*Saccharomyces cerevisiae*
Growth in vitamin-free medium	+	
Growth in biotin-free medium	+	
Tolerance to ethanol (% concentration)	20–23	16–19
Habitat	Found only in saké brewing	Widely found in fruits and other environments

into the 'moromi' as it progresses (Figure 2). (Moromi is a general term to describe a fermenting mash based on grains on which fungi have grown.) The moromi stage of the process involves putting moto, at 12–13 °C, in a vessel 6–18 kl in size along with steamed cool rice, rice-koji and water (Table 3). By this stage, the water phase of moto has a specific gravity of 1.028–1.043, an ethanol content of 12–15%, amino acid content of 0.45–0.65% and total acid content of 0.9–1.0%. The saccharolytic enzymes from the koji release the glucose from the rice starch thus making it available for the yeast to ferment.

There are three additions of water, rice-koji, and steamed rice to the vessel containing the moto, and as each addition is made the temperature is lowered by adjusting the temperature of the steamed rice and water so that by the fourth day the temperature

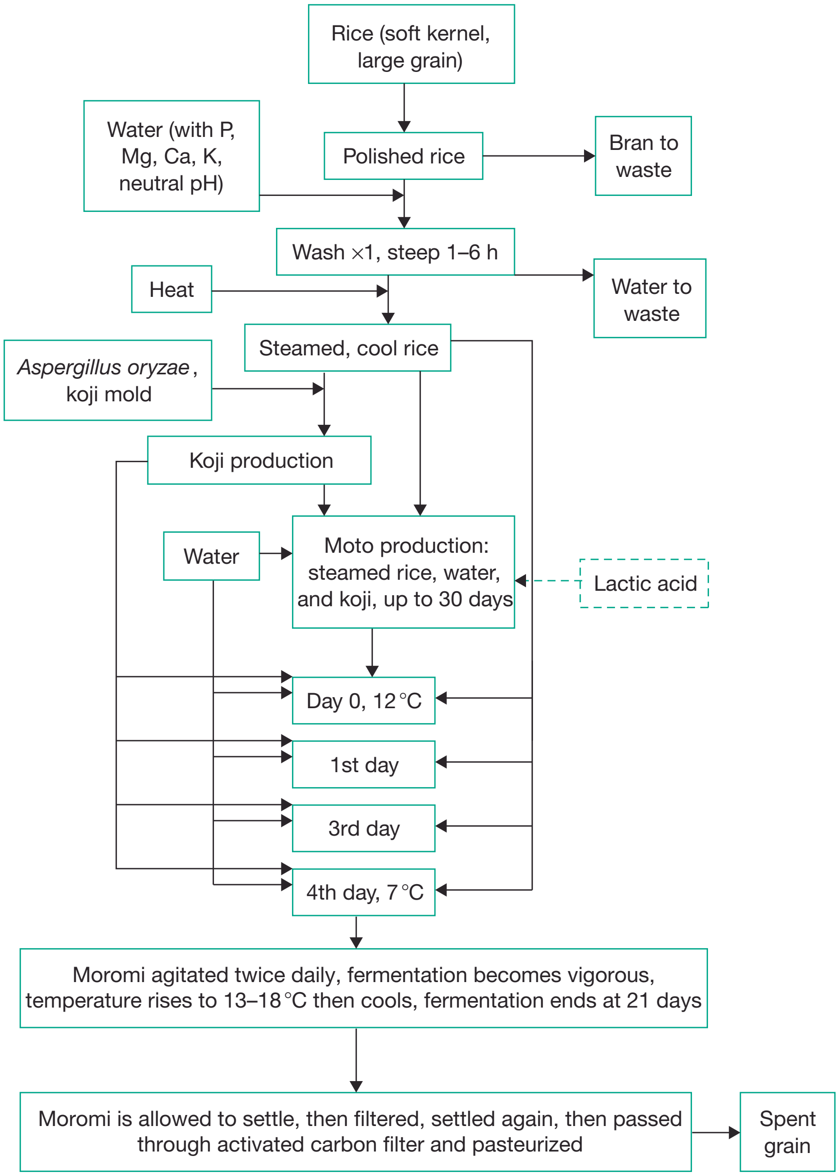

Figure 2 Saké production is a complex process involving the production of koji that is used to make a relatively small batch of starter material, the moto, to which is added further batches of steamed rice, koji, and water. Acid conditions to prevent growth of spoilage organisms are important; so in some cases lactic acid is added instead of relying on the natural growth of lactic acid bacteria in the moto. Temperature control is also important.

Table 3 The raw materials added progressively to the prepared moto to ferment the rice for saké

		Cumulative totals			
Preparation stage	*Day*	*Total rice (kg)*	*Steamed rice (kg)*	*Rice-koji (kg)*	*Water (l)*
Moto[a]	0	180	120	60	270
1st addition	1	510	360	150	500
2nd addition	3	1020	830	210	1230
3rd addition	4	1710	1350	360	2329
Total		3420	2640	780	4329

[a]Moto production takes 2–4 weeks to complete before the actual wine production begins.

is 7–8 °C. The lower temperature controls wild microbial growth. The moromi is then agitated twice daily and by 3–4 days, the water phase composition is: specific gravity, 1.051–1.058; ethanol, 3–4%; total acid as succinic acid, 0.06–0.07%.

The yeast concentration reaches about 2.5×10^8 per g and the fermentation becomes more vigorous and temperature rises to about 13–18 °C in 6–9 days, where the temperature is held for a further 5–7 days until the ethanol content is 17.5–19.5% and the temperature begins to decline.

In the final stage, further additions may be made to the moromi. Pure distilled ethanol may be added to bring ethanol to 20–22%, 7–8% steamed rice allows production of excess glucose to sweeten the wine but pure glucose may be added, lactic acid and succinic acid may be added as well as glutamic acid. By 21 days, the density of the water phase is 1.004–1.000, reducing sugar is 3–2%, ethanol is 18.5–19.5% and the acid content as succinic acid is 0.14–0.16%.

The moromi is allowed to stand for a few days to settle and it is then filtered and again allowed to settle for 5–10 days. If the period is too long, the saké quality begins to deteriorate. It is then passed through an activated carbon filter, pasteurized, and stored at 13–18 °C to mature before bottling.

Scientific Basis of Process

The wine-brewing process is conducted as a parallel fermentation, and is best conducted at low temperatures. Further, the development of low pH due to acid production by lactic acid bacteria or addition of lactic acid retards growth of spoilage organisms and permits the growth of yeasts. The parallel fermentation is unique in that while the enzymes are releasing the glucose from the starch, the yeasts are fermenting it to produce ethanol unlike beer where the soluble sugars are first released and then the fermentation is conducted.

From studies conducted in Japan, it is known that the release of the sugars initially from the steamed rice occurs rapidly. However, the increased glucose concentration suppresses α-amylase activity, so release of glucose declines until significant yeast activity reduces glucose and produces ethanol. The breakdown of the rice-koji in the moromi is more complex. The mold growth in the outer layers of the rice grain solubilizes the outer layer of starch rather quickly leaving variable amounts of a core of the rice grain that breaks down much more slowly under the action of the α-amylase. The breakdown of this inner core is dependent on the variety of rice used in the manufacturing.

Table 4 The Chinese classification of rice wines

Wine type	*Sugar (g per 100 ml, as glucose)*	*Ethanol (%, v/v)*	*Total acid (g per 100 ml, as succinic acid)*
Dry type	<0.5	>14.5	0.45
Semidry type	0.50–3.00	>16.0	0.45
Semisweet type	3.00–10.00	>15.0	0.55
Sweet type	>10.00	>13.0	0.55

Chinese Rice Wine Production

Unlike modern Japanese saké preparation methods, the Chinese traditional methods of preparation did not distinguish between the mold stage and the yeast stage, they were combined into one process that was very complex and varied enormously from place to place. However, pure cultures have been isolated and are increasingly being used but traditional methods are still used. In addition, constituents apart from rice may be used in the preparation so instead of steamed rice, barley, and millet are also used as the main source of starch.

Generally, Chinese rice wines are classified according to the residual sugar level, namely dry type, semidry type, semisweet type, sweet type, and extrasweet type (Table 4). They are also classified according to the production method. The four basic methods and their names (Table 5) are:

1. 'Ling fan jiu,' e.g., 'yuan hong' wine is a dry type wine. The hot steamed rice is cooled by drenching it with cold water then mixing the rice with jiuqu starter. It is commonly used as starter for inoculating more mash. It can be drunk after fermentation for several days.
2. 'Tang fan jiu,' e.g., 'jia fan' wine that is a semidry type wine. The steamed rice is spread onto bamboo rafts to cool and then mixed with jiuqu, and acidified rice-steeping liquid.
3. 'Wei fan jiu,' e.g., 'san niang' wine that is a semisweet type wine. This rice wine is produced using a fed batch fermentation method similar to saké production. The fermentation is begun as in the first process, but then steamed rice is added intermittently during the fermentation period, usually in three batches.
4. Fortified rice wine, e.g., 'xiang xue' wine that is a sweet type wine. Aged rice wine or spirits distilled from refermented spent grains from rice wine are added before the main fermentation ceases. The final alcohol concentration is above 20%, consequently the microorganisms in the mash are inhibited, but the saccharification of the remaining dextrin to sugar in the main mash continues slowly, resulting in high residual sugar contents.

A general outline of the manufacturing process of Chinese rice wine is given in Figure 3.

Table 5 The ingredients and chemical composition of four kinds of Chinese rice wine

Component	*Types of rice wine* Yuan hong	Jia fan	San niang	Xiang xue
Proportions of components used to make the rice wine (kg)				
Glutinous rice	144	144	144	100
Wheat koji	22.5	25	25	10
Seed mash	8–10	8–9	15	
Acidified rice-steeping water	84	50	50	
Freshwater	112	68.6	100[a]	
Distilled spirit		5		100[b]
Composition of rice wines				
Specific gravity	0.992	0.995	1.0349	1.073
Ethanol (%, v/v)	15.6	17.8	16.7	19.4
Extracts (g per 100 ml)	3.325	4.450	15.65	24.44
Sugar (g per 100 ml)	0.38	0.78	6.50	20.00
Total acids (g per 100 ml)	0.48	0.46	0.46	0.28
Volatile acids (g per 100 ml)	0.06	0.027	0.054	0.056
Nonvolatile acids (g per 100 ml)	0.42	0.43	0.406	0.22

[a]This is yuan hong wine.
[b]This is 50% distilled spirit.
Adapted from Xu G and Bao TF Grandiose survey of Chinese alcoholic drinks and beverages (http://www.sytu.edu/zhgjiu/umain.htm).

Jiuqu Production

Chinese rice wine making begins with the preparation of a starter material called qu or jiuqu. The preparation is designed to encourage the growth of molds on prepared masses of grains and along with it yeasts also grow. The mold growth results in the production of enzymes in the jiuqu. The molded mass of grains is then shaped and dried for use as an inoculum in rice wine making. When the jiuqu is then added to prepared grains, such as steamed rice, the enzymes breakdown starch in the steamed rice just as malted grains can be used to breakdown adjuncts in beer production. However, unlike beer production, the jiuqu also fills the fermenting function, due to the presence of yeasts (*S. cerevisiae*) in the prepared jiuqu. The actual number of types of jiuqu used for the production of alcoholic beverages in China is unknown. However, there are three broad types of jiuqu, based on the raw material used, and within each broad type there are subtypes based on the color, presence of additives, and size of the molded masses or molded pancakes produced. The names of various jiuqus based on the raw materials rice and wheat are in Table 6. One is also made from wheat bran, called 'fu qu,' that is used for alcohol production. The manufacturing processes also vary which also influence the resulting jiuqu. These processes include the use of pure or mixed cultures, a high temperature or a medium temperature, incubation of jiuqu in a thin or a thick layer, hanging in the air in a suitable small container, and wrapping the jiuqu in straw. Consequently, for a given mass of jiuqu, the enzyme activity varies widely. In addition, jiuqu is prepared to suit the product to be manufactured.

Shenqu

Historically, the most active wheat-based jiuqu for making rice wine, was 'shenqu.' It was made by milling wheat, splitting it into three portions, one of which was roasted, another steamed, and the other left uncooked. The three portions were then mixed thoroughly with added water to a consistency that was less than a slurry. The mixture was transferred to an incubation room, and spread on the floor. Moisture content and temperature were critical and these were managed by opening windows to lower temperature and heaping the mixture to raise temperature. The first three days required high-moisture content, to promote growth of mycelia, and lower-water content was required for the subsequent incubation period up to 49 days. After this time, the shenqu had a yellowish to yellowish-green color. The primary fungi for this preparation were *Aspergillus* species and pure cultures have been isolated and are now used.

Preparation methods today with pure cultures differ from the traditional method in that incubation may be on the floor, as in the traditional method, or in a compartment similar to the germinating compartment used for malting barley, or in trays similar to koji trays. Using the compartment, the steamed, cooked wheat grits are inoculated with fungal spores and piled in a heap for 3 h. The wheat is then spread in a 30 cm layer over the perforated plate in the compartment. The temperature and moisture content are controlled, and oxygen supplied for the fungi deep in the pile, by blowing air suitably conditioned for temperature and water content through the layer. Generally, the temperature is kept to a maximum of $\sim 30\,^{\circ}C$.

Daqu

Daqu, meaning 'large qu,' is used for the manufacture of some Chinese spirits and its manufacture is different from shenqu. There are two basic kinds, depending on the temperature reached during manufacture. One kind is high temperature that is allowed to rise above 55 °C, perhaps as high as 65 °C, and the other is kept below 55 °C. The raw materials are wheat flour, barley flour, and pea flour mixed together in proportions, depending on the manufacturer. One manufacturer, Yanghe Distillery, uses the following proportions and procedures. The wheat:barley:pea proportions are 5:4:1. The

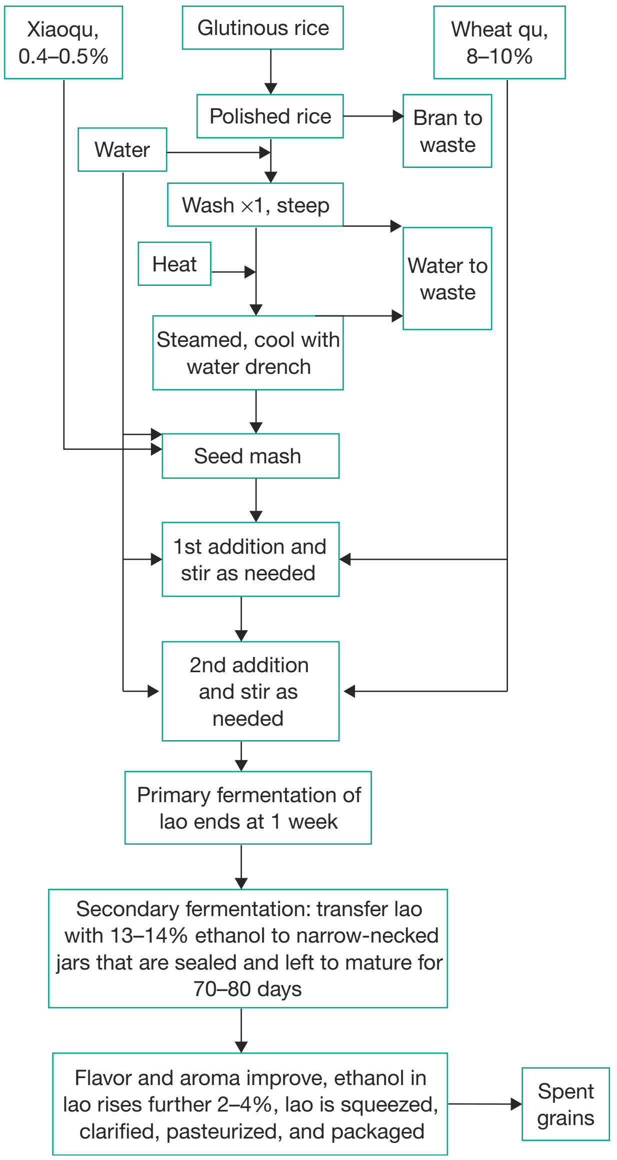

Figure 3 The production of a Chinese rice wine. The name 'lao' is equivalent to moromi in saké manufacturing. In this case, there is a secondary fermentation in which the lao is put into a jar and sealed up for months to allow the production of flavors and aromas.

moisture content is brought to ~40% and the resulting dough kneaded and eventually packed into a wooden mold with dimensions of ~195 × 138 × 75 cm. Traditionally, the packing was done by human treading by ten people with a gradation in body weight to get the dough at just the right firmness in the mold (Figure 4). In modern production systems, mechanical pressing devices are used to prepare the blocks. The block is then removed from the wooden mold and placed in the incubation room, with other blocks, in two layers on bamboo rods giving a space of 2 cm between the layers covered with straw. Incubation is for ~4 weeks and has three phases. In the first phase of ~9 days, there is a rapidly rising temperature due to the growth of fungi and yeasts. The dominant fungi are *Aspergillus* species and *Rhizopus* species, namely *R. oryzae* and *R. chinensis*. The humidity is initially high and is reduced by opening windows. The temperature of the whole batch is controlled to the temperature range 30–45 °C by turning and rearranging blocks ~6 times in the 9-day period. In the second phase, of ~8 days' duration, the temperature of the batch is allowed to rise smoothly a little further but within the range 30–45 °C. In this phase, more of the moisture evaporates and its loss is controlled so that it is not lost too quickly. In the third phase, the room temperature is allowed to decline and moisture loss from the blocks allowed to increase so that they

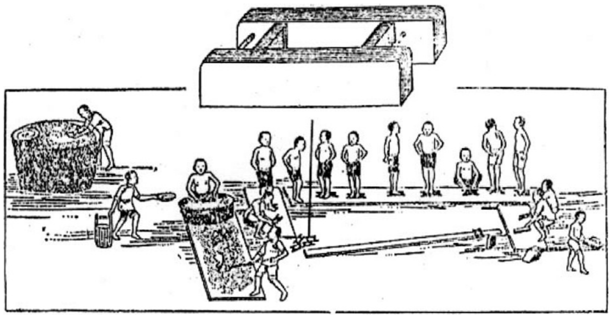

Figure 4 An ancient image of daqu production in China. In the early stage, the 'dough' is shaped into rectangular blocks by men pressing the dough into a mold with their feet. The weight of the men pressing a block progressively increases. The block is then managed to encourage mold and yeast growth, before drying the blocks. (Data from Xu G and Bao TF Grandiose survey of Chinese alcoholic drinks and beverages (http://www.sytu.edu/zhgjiu/umain.htm))

Table 6 Types of Chinese qu, based on the base grain employed to make alcoholic beverages from rice and other grains

Rice		*Wheat*	
Qu name	*Comment*	*Qu name*	*Comment*
Xiao qu	White, small dimension, made with *Rhizopus* spp.	Mai qu	Wheat qu, made with *Aspergillus flavum*
Yao qu	Herbs added	Da qu	Dimension large
Bai qu	White	Shu mai qu	Wheat steamed or roasted
Hong qu	Red color, due to *Monascus* fungus	Seng mai qu	Fresh wheat used
Hei qu	Black, due to *Aspergillus niger*	Bing qu	Pancake shape
Wu yi hong qu	Red and black color	Dou qu	Added pea or bean, and rice or wheat flour

weigh less. If at the end the moisture has not been reduced to ~12%, the blocks are piled and recovered with straw to raise the temperature and accelerate moisture loss.

Xiaoqu

A further important jiuqu is 'xiaoqu.' The traditional method is similar to that used for daqu production except only steamed and powdered rice is used, the water used is flavored with steeped herbs, and the freshly made blocks are cut into smaller cubes and formed into balls. Selected old jiuqu is used as a seed culture to inoculate the outer surface of the balls. The old jiuqu is a kind of selected starter culture. As the dominant fungi involved have been isolated, a pure culture method is now used in its preparation as follows. The *Rhizopus* species are grown on rice meal or wheat bran and the yeast, a *Saccharomyces* species, is cultured on an extract of a special jiuqu and harvested by centrifugation. Then the *Rhizopus* culture and yeast concentrate are mixed in a 50:1 ratio. This mixture is used to make a seed mash for rice wine. This particular approach to rice wine making significantly reduces the time to make the wine.

Chinese Rice Wine Making

Although Chinese rice wines are usually made with rice, they are also made with maize and millet. When made with rice, ~230 kg of rice wine is produced from 100 kg of rice. The jiuqu in rice wine manufacturing has two functions: to supply amylolytic enzymes and to supply yeast for ethanol production. In some modern production systems, commercially manufactured enzymes are used to carry out the saccharification step. For various types of wines different portions of ingredients are used (Table 5).

One of the ingredients in the mix is traditional seed mash, and the ingredients used to make this seed mash are 125 kg of glutinous rice that is soaked for several days and then steamed. The steamed rice is then spread in a ceramic vat and after it cools to ~27–30 °C, half of the xiaoqu jiuqu is mixed through the rice (Figures 3 and 5). The rice is then stacked around the sides of the vat to form a hollow in the middle of the rice and the rest of the xiaoqu powder is sprinkled onto the surface (0.187–0.25 kg total). This maximizes the surface exposure to encourage growth of *Rhizopus* species (that produce lactic and fumaric acids) to lower the pH, discourage the growth of undesirable organisms, and encourage yeast growth. In addition, the amylase and glucoamylase in the jiuqu saccharify the rice. After about 2 days a pool of liquid containing sugars, etc., gather in the hollow. Then 19.5 kg of jiuqu is added, mixed through the fermenting rice mix and freshwater added to bring the total water content, including that taken up by the rice during steeping and steaming, to 230 kg.

Water and Acidified Rice Steeping Liquid

The water used in wine brewing should have a hardness in the range of 2–6, ~pH 7, and should have a low-iron content. The acidified rice-steeping liquid is traditionally prepared by steeping the polished rice in the water for periods of 10–20 days, preferably 13–20 days. During the steeping, lactic acid bacteria grow and lower the pH. This traditional liquid, when added to the final brew, helps to inhibit the germination of bacterial spores and growth of vegetative cells, provides amino acids and vitamins, lowers the pH for yeast growth, and helps improve the flavor of rice wines. However, alternatives to this include using diluted vinegar solution or a broth made with wheat flour, but lactic acid is now commonly added.

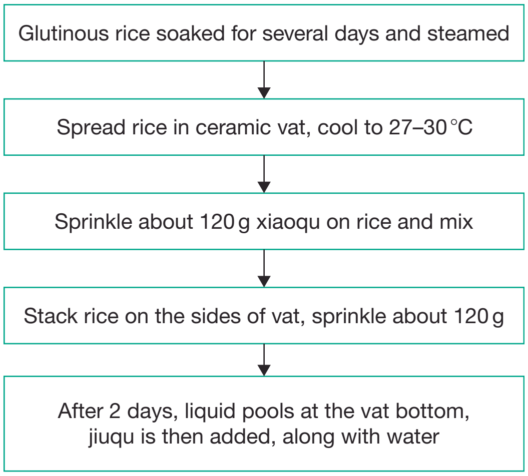

Figure 5 The production of seed mash used in the manufacture of Chinese rice wines.

Table 7 Some of the jiuqu mold preparations used in the manufacture of Chinese distilled liquors and the names of liquors based on distinctive aromas and flavors and their characteristic flavor impact compounds

Jiuqu used	*Aroma and flavor*	*Flavor-impact compound*
Daqu	Maotai	
Xiaoqu	Luzhou	Ethyl hexanoate and ethyl butyrate
Fuqu	Fen	Ethyl acetate
	Rice	Ethyl lactate and ethyl acetate

Chinese Distilled Liquors

Chinese distilled liquors are classified according to the jiuqu used, the type of aroma and flavor developed, the fermentation state for ethanol production, the quality, the ethanol content and the raw materials used. Important types are in Table 7 along with the characteristic flavor impact compounds. Many Chinese liquors are based on sorghum and contain 53–55% ethanol. They have characteristic aromatic fragrance due to the presence of 4-ethylguaiacol, vanillic acid, and vanillin. The hexanoic acid needed to result in ethyl hexanoate comes from the metabolic activity of anaerobic bacteria in the fabric of the fermentation pits. A difference between Chinese-distilled sorghum liquor and Western-distilled grain liquors is the use of external mold enzymes from koji-like products.

The production processes vary. For rice spirit, the rice is washed, steamed, cooled, inoculated with xioaqu, and placed in a ceramic vat to allow the enzymes to breakdown the starch. Then water is added and the vat covered for 7 days to allow yeast growth and then the fermented liquid is distilled. For sorghum, the grains are crushed, mixed with hot water, steamed, cooled, and further water added. Daqu is added to the cooled mixture in a ceramic vat or mud pit or stone pit and sealed. The fermentation is allowed to proceed for 3–4 weeks and the steamed sorghum husks added and the mixture distilled. The spent sorghum is then remixed with daqu and sealed in a vat and left for 3–4 weeks whereupon steamed husks are added again and the mixture distilled again.

The production system in Taiwan is of rather shorter duration. The typical 'wine cake' (or juiqu) for spirit production is produced with cracked wheat, contains up to five varities of yeasts (including *S. cerevisiae* and *S. fibuligera*); four molds (including *Mucor* and *Rhizopus* species); and six types of bacteria, including a *Clostridium* species. The level of activity of hydrolytic enzymes is usually low.

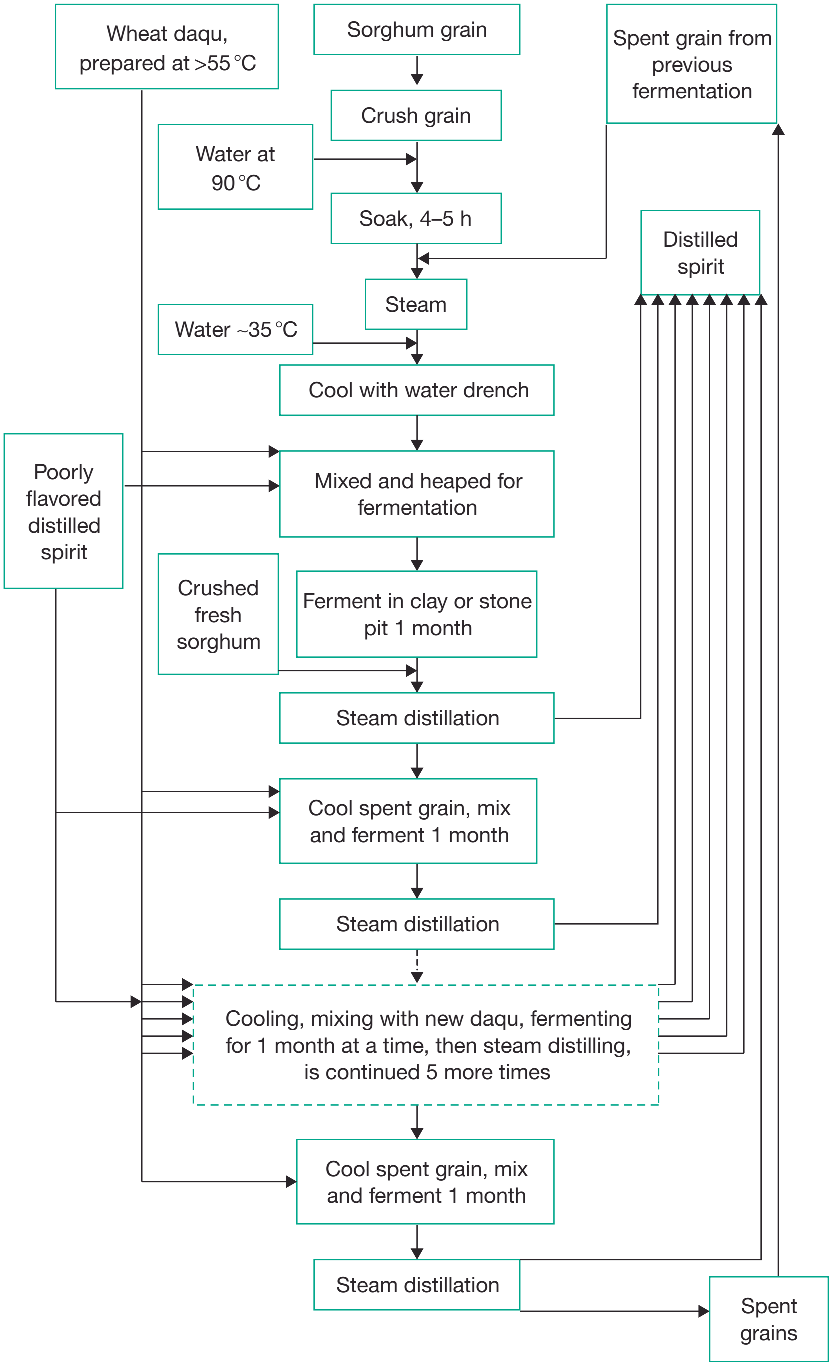

Figure 6 The traditional Chinese method of preparation of sorghum-based distilled liquors. The amount of daqu and sorghum used is ~1:1. The traditional pit used for the fermentation is the source of particular flavors for some liquors due to associated bacterial activity. Eventually, the completely spent grain is discarded.

The steamed sorghum is spread out on the floor to a thickness of ~5 cm and powdered wine cake mixed through it. The moisture content of the sorghum is ~55%. The fungi grow on the cool and dry surface, whereas bacteria and yeasts grow within the wet mass of sorghum. After 24 h, the sorghum is piled into heaps that encourage growth of yeast in an anaerobic and warm environment (prefermentation). The size of the pile is restricted because the internal temperature of the pile must not be allowed to rise above 40 °C, and the heat produced metabolically is not easily dispersed. The Taiwanese put the inoculated sorghum into stainless steel tanks or boxes and cover them with polythene sheet to prevent moisture loss and reduce aeration. Microbial growth and metabolism is allowed to progress for up to 10 days after which the mixture is put through a steam distillation to remove the ethanol. The pile of sorghum is reinoculated to encourage further growth and when ready the sorghum is distilled again. Each heat treatment, or steaming, causes partial hydrolysis of starch, carbohydrates, and protein. Steaming also removes the alcohol that prevents yeast cell growth in the thin film of water surrounding sorghum grains. Alcohol is collected by condensation of the distillate and the ethanol yield is ~22.53 kg per 100 kg of sorghum.

Microbial cells grow slowly on sorghum due to low availability of fermentable substrates, and this leads to the production of secondary metabolites mentioned above, which contribute to the characteristic strong aromatic fragrance of sorghum liquor.

In mainland China, the production of sorghum liquor is much more complex and it takes about 1 year to complete the distillations. The process begins with sorghum that is crushed, soaked in hot water, spent grain from a previous fermentation added and then the entire mix is steamed. Spirit of lower quality and the inoculum of daqu is added to the cooled mixture (Figure 6). It is heaped to allow the fermentation to begin and then placed in a fermentation pit for up to a month to allow the fermentation process to take place. The mixture is then steam-distilled, more daqu added, and the fermentation conducted all over again. With slight variation the process is conducted up to 8 times.

Exercises for Revision

- Write out a detailed process flow diagram for a selected product from this chapter. Identify all possible sources of variability in final product quality.
- Suggest methods for identifying and controlling the microbial strains present at each stage of processing.

Exercises for Readers to Explore the Topic Further

- Investigate the marketing of Asian sorghum-based distilled liquors – what factors influence pricing?
- What is known about sensory testing and preferences for the beverages discussed in this chapter.

See also: **Beverages from Grains**: Beverages: Distilled; Fermentation: Origins and Applications; **Proteins**: The Enzymes Associated with Food Grains and Their Functions in Processing.

Further Reading

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Relevant Websites

enonline.sh.cn http://www.enonline.sh.cn – Shanghai online.

sytu.edu.cn http://www.sytu.edu.cn – A site of the Southern Yangtze University in China. Contains an English translation of a wide-ranging survey of alcoholic drinks and beverages in China from an historical viewpoint to the technology used as well as aspects of the legal and regulatory side of the industry.

foodreference.com http://www.foodreference.com – A site dealing in general with all aspects of food. It includes daily food and beverage news, a culinary quiz and a 'Today in food history' section. There is a wealth of information. Use of search function to search for 'rice wine.'

internationalrecipesonline.com http://www.internationalrecipesonline.com – Recipes for using rice wine are available on the site using the search function.