The Story of Sake

Sake(Seishu) 2
(The Integration of Science and Technology)

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Ginjo-shu has a fine fruity aroma and exquisite mouthfeel. Junmai-shu has moderate sweetness and great palatetfulness. These two types of sake significantly changed its stereotyped image. The market share on shipment basis of ginjo-shu and junmai-ginjo-shu has been increasing year by year. Japanese term Ginjo literally means carefully selected and brewed. So ginjo-shu is the culmination of sake brewing technology, embodying the craftsmanlike spirit of sake brewers throughout the brewing processes of sake. Sophisticated brewing technology through the development of ginjo making has contributed to the quality improvement of the whole sake industry. The integration of the traditional skills of the sake brewers (called toji and kurabito) and cutting-edge sake research by scientists has led to the production of not only ginjo-shu but also various types and kinds of deep flavored and high quality sake.

This booklet The Story of Sake 2 introduces a more detailed and deeper discussion of how sake is made, including the integration of science and technology. This booklet also introduces the processes that were not included in The Story of Sake 1, from the step of pressing the fermentation mash to shipping sake as a finished product. It also provides information about the types and storage management of sake.

We hope you will enjoy sake more, after learning about the features of each type of sake, including the different designations derived from respective ingredients and brewing methods.

The beginnings of the science of sake brewing

Sake manufacturing industry is one of the major time-honored fermentation industries in Japan. Toward 1887, the modern sake manufacturing industry established. Simultaneously, the mass production by private sake companies began in Nada in the Hyogo Prefecture and Fushimi in the Kyoto Prefecture.

At that time, however, sake brewing relied on the experience and intuition of the sake brewers, and therefore the production process was unstable, and frequently lead to spoilage of sake. Research and development, e.g. the isolation of indispensable microorganisms for sake brewing, koji mold and yeast were just beginning. However, it was still a long time before we attained a full scientific elucidation of sake brewing.

Besides, by 1899 the liquor tax had become the biggest source of revenue for the Japanese government, exceeding even the land tax. When sake spoiled, the prepaid tax had to be returned, meaning revenue derived from liquor tax was not stable.

The elucidation and countermeasure against sake spoilage came to an urgent matter. Academic research and investigations into how to improve sake brewing technology began as a national project essential to supporting the basis of national revenue.

With this background, the National Research Institute of Brewing (NRIB) was established within the Ministry of Finance in 1904.

Specially designated sake

<table>
<thead>
<tr>
<th>special designation</th>
<th>ingredients</th>
<th>rice-polishing ratio (percent)</th>
<th>percent of rice for making sake</th>
<th>other features</th>
</tr>
</thead>
<tbody>
<tr>
<td>ginjo-shu</td>
<td>rice, rice koji, distilled alcohol</td>
<td>up to 60% or 70%</td>
<td>at least 15%</td>
<td>rice making, excellent flavor and appearance</td>
</tr>
<tr>
<td>jummai-shu</td>
<td>rice, rice koji</td>
<td>-</td>
<td>at least 15%</td>
<td>good flavor and appearance</td>
</tr>
<tr>
<td>jummai-ginjo-shu</td>
<td>rice, rice koji</td>
<td>up to 60% or 70%</td>
<td>at least 15%</td>
<td>rice making, excellent flavor and appearance</td>
</tr>
<tr>
<td>tokubetsu-jummai-shu</td>
<td>rice, rice koji</td>
<td>up to 60% or 70%</td>
<td>at least 15%</td>
<td>rice making and excellent flavor and appearance</td>
</tr>
<tr>
<td>horin-puro-shu</td>
<td>rice, rice koji, distilled alcohol</td>
<td>up to 60%</td>
<td>at least 15%</td>
<td>rice making, excellent flavor and appearance</td>
</tr>
</tbody>
</table>

1. The rice used has to be pass an inspection based on Agricultural Product Inspection
2. The amount of distilled alcohol usage should not exceed 10% of rice weight
3. The rice-polishing ratio has to be indicated on label

Special designations and their specifications
Rice for sake brewing

Sake is an alcoholic beverage made from rice. Currently, about 300 varieties of rice are cultivated in Japan. Some varieties of them are used to brew domestic sakes. Some kinds of rice classified by the Agricultural Product Standards as “brown rice for sake brewing” are also referred to as “sake-brewing rice.” They have superior properties that make them the most suitable for being used as the ingredient for brewing sake. Among the sake-brewing rice varieties, the most cultivated variety was Yamadanishiki. In addition to Yamadanishiki, many varieties of sake-brewing rice are grown, throughout Japan.

Sake-brewing rice has large grains and often has an opaque white core called shimpaku in the center of each grain.

Sake-brewing rice is lower in protein content than table rice. The grains break down easily during the long, low-temperature fermentation process, resulting in good and consistent fermentation. Polished white rice, not brown rice, is used to make sake.

The outer part of brown rice contains lots of lipids, minerals and protein. Too much of these components will cause unpleasant flavor. That’s why these parts must be removed by rice polishing.

Yamadanishiki

Yamadanishiki is a sake-brewing rice that was cross-bred in Hyogo Prefecture. Yamadanishiki was developed in 1936 through 13 years of cultivation tests after cross-breeding at the Agricultural Experiment Station, Hyogo Prefecture. All of Japanese Toji (chief sake brewers) especially prefer to work with this variety of rice because it produces good tasting sake with good physical properties. It grows up to 130cm and the ears bow archwise at the time of harvest. Yamadanishiki accounts for 33% of the sake-brewing rice harvested in Japan. Approximately 71% of it is produced in Hyogo Prefecture (the result of agricultural product inspections of rice in FY 2014).

The following equation states the rice-polishing ratio, used to show the degree of polishing.

\[
\text{Rice-polishing ratio} = \frac{\text{Weight of the white rice}}{\text{Weight of the brown rice}} \times 100(\%)
\]

The table rice we normally eat has a rice-polishing ratio of approximately 90%. This means 10% of the exterior of the grain has been removed as bran. We consume the remaining 90% as white rice. The specially designated sakes are classified according to the rice-polishing ratio. They are required to be made of rice of the following rice-polishing ratios: Honjozo-shu, up to 70%; ginjo-shu and jummai-ginjo-shu, up to 60%; daiginjo-shu and jummai-daiginjo-shu, up to 50%. Jummai-shu is a special case with different requirements.
Rice processing

Washing, soaking and steaming rice are referred to as rice processing. Well-steamed rice is the basis of good sake brewing. It is a process sake brewers are very sensitive to. The moisture content in steamed rice has a significant impact, almost single-handedly determining the quality of the finished sake. Too much moisture content will cause the rice to break down too much during fermentation, and therefore produce too many components of taste. If the correct balance between the decomposition level of the steamed rice and the alcoholic fermentation by yeast is not achieved, it becomes difficult to fine-tune the flavor of the sake.

In order to produce steamed rice with the appropriate moisture content, first we must precisely control the amount of water to soak the rice before steaming. For the purpose, we have to ascertain the quality of the rice, measure the water temperature, try a test-washing, and determine the correct length of time to soak the rice. By precise control we mean achieving a ±1% level of accuracy of the amount of water absorbed. Controlling the water content of rice by means of curtailing soaking time is referred to as Gentei-Kyusui (limited water absorption). Especially for ginjo making, the entire brewing staff joins the process of washing rice, soaking it, and draining it, in order to hit the precise water absorption target.

Water

Approximately 80% of sake is water. In order to make delicious sake, we must obtain very high quality water that does not contain iron, because iron causes coloration of the sake. This section describes the water used by sake brewers in the two largest sake-brewing areas in Japan: Miyamizu (Miya water) in Nada and Gokosui (Goko water) in Fushimi.

Miyamizu in Nada

In the latter part of the Edo era, Mr. Tazaemon Yamamura, who had sake breweries in Uozaki, Kobe, and also in Nishinomiya, wanted to find out why his Nishinomiya brewery always produced higher quality sake than his Uozaki brewery.

He changed koji (chief sake brewers) and tools of Uozaki with those of Nishinomiya, but this did not provide reliably good results. In 1840, when he brought water from Nishinomiya to Uozaki to make sake, the Uozaki brewery produced good quality sake. Rainwater on Rokko Mountain infiltrates into the soil and flows out of springs around the Nishinomiya Shrine. This spring water is the secret for the production of excellent sake. From that time, sake brewers in Nada began to use Nishinomiya water. People abbreviated the water from Nishinomiya as “Miya water” – Miyamizu. Miyamizu is hard water. Sake made in Nada using this hard water has a dry and crisp taste, so it is referred to as Otoko-zake (Men’s sake).

Gokosui in Fushimi

Fushimi in Kyoto City is a land blessed with a large amount of good quality underground water. One place where this water emerges from the ground is at Gokonomiya, a shrine near Momoyama-goryou-mae Station on the Kintetsu Kyoto line. The water from this spring is called Gokosui. This shrine was named after Gokosui (perfumed water) by the Emperor Seiwa, because water with a pleasant aroma sprang up in this shrine on September 9, 862. In Fushimi, in addition to Gokosui (also called Iwai-no-Mizu) there are six other sites where good water can be found. They are called the “seven wells of Fushimi.” Gokosui is medium-hard water; that is, it is softer than Miyamizu in Nada. Sake made with this water is smooth and silky, so it is called Onna-zake (women’s sake).
Koji mold (Aspergillus oryzae)

Koji mold has been named the National Fungi of JAPAN by the Brewing Society of Japan. It has been used to produce sake since ancient times. Besides being used for sake brewing, koji mold is also used for making such traditional Japanese products as shochu (a Japanese white spirit), awamori (an Okinawan spirit made with black koji only), miso, soy sauce, vinegar, and pickles.

Koji is cultured koji mold on rice, barley, beans, and so on. Rice koji, used for making sake, is of course grown on rice. Koji mold digests the rice using enzymes, converting starch to glucose. Then yeast eats the glucose to carry out the process of alcoholic fermentation.

Making koji (seikiku)

After washing, soaking and steaming of rice, the next step in brewing sake is making koji. There are two well-known features for growing koji. One is the Sohaze-Koji condition. This is when the koji is entirely covered with hyphae of koji mold called haze which looks like white. The other is called Tsukihaze-Koji. This koji has some haze area on the surface which has grown into the steamed rice. Both of them are considered to be good koji. Generally, tsukihaze-koji is used when brewing ginjo-shu. Tsukihaze-koji is especially rich in glucoamylase, which breaks down starch into glucose, and it does not have so much protease, which breaks down protein into amino acids that impart taste. Therefore, the tsukihaze-koji can supply enough glucose to nourish the yeast, permitting a long lasting fermentation at a low temperature. Sake made with this koji turns out a light and delicate taste.

The safety of koji mold

Koji mold, which has been named after the National Fungi of JAPAN, can be classified into three types, according to color. Yellow koji mold (Aspergillus oryzae) is chiefly used for brewing sake. Black koji mold (Aspergillus luchuensis) is chiefly used for brewing shochu and awamori. White koji mold (Aspergillus kawachii) is a mutant strain of black koji mold. There are actually many mutant strains of each koji mold.

Yellow koji mold grown on rice has been used since ancient age for brewing sake. In 1960, it was reported in the UK that some strains of Aspergillus flavus, a species related to yellow koji mold, produces aflatoxin, which is a kind of mycotoxin. So, it came to a matter that even yellow koji mold might produce aflatoxin. NRIB immediately began to research this issue. In 1971, we clearly determined that the yellow koji mold group is different from the Aspergillus flavus group, and that yellow koji mold does not produce aflatoxin. This research proved that sake made with yellow koji mold is safe to consume. Then, in 2009, research at the genetic level proved that yellow koji mold does not generate aflatoxin.

Also black and white koji molds had already been confirmed to be safe. It was reported in 1994 that some strains of Aspergillus niger, a relative of these molds, produces ochratoxin, a kind of mycotoxin. We analyzed black koji mold, white koji mold, and Aspergillus niger in 2009 on the genetic level. We proved that black koji mold and white koji mold belong to a different group from that of Aspergillus niger, and that they do not produce ochratoxin or aflatoxin. We continuously conduct research on the safety of not only koji mold but also yeast and sake itself, as well as the effects of sake on human health.
Excessively steamed rice is unable to grow good koji. Sake brewers control moisture content and temperature to produce sahaze-koji or tsukihaze-koji according to the aimed quality of sake. It takes approximately two days to grow koji.

On the first day, the steamed rice is cooled down to the appropriate level and brought into the koji-making room. Then the steamed rice is spread on a table called toko, and koji mold spores are seeded across the entire surface. After the spores are seeded, the steamed rice is covered with a cloth to maintain the correct temperature and humidity. The rice rests for that first day on the toko. During this stay, the koji mold spores germinate. The first day is referred to as the toko period.

On the second day, the koji being produced is transferred into shallow trays, called koji-bako and koji-buta. This transfer task is referred to as mori. Amount of koji for a koji-bako is 15 to 30 kg, and for a koji-buta is 1.5 to 2.5 kg. As the hyphae of the koji mold grow, they generate heat, so the brewers have to control koji temperature to avoid it rising too much. The second day, when the koji mold is kept in the trays, is called the tana period.

When the temperature of the koji reaches 40 to 43 degrees Celsius, and after 43 to 45 hours (sometimes more than 48 hours when using the tsukihaze-koji process) has elapsed since the rice was brought into the koji-making room, koji making is complete. Good koji has a soft elasticity when grasped by the hand and it does not stick to the hand after being released. With good koji, you experience a light sweet taste and an aroma like roasted chestnuts.

### Yeast

The alcohol in sake is made by yeast. There are many kinds of yeast living in the natural environment. Natural yeasts grow on fruit juice when a fruit is injured. Also, there is wild yeast adhering to brown rice and white rice grains. There are many kinds of yeast. Some of them are used for making bread, others for making soy sauce and for making miso. The yeast called Saccharomyces cerevisiae is the chief one used for brewing sake. The term “Saccharomyces” comes from the words for sugar and mushroom in Greek. The term “cerevisiae” comes from the Latin for beer.

Yeast generates ethanol and carbon dioxide gas from the glucose that the koji made by breaking down the starch in the rice. Yeast also produces many flavor components, in addition to ethanol.

The aroma and taste components produced by yeast vary with each yeast type, so the aroma and taste of sake depend on the specific yeast used. Therefore, the selection of purified yeast from ferments of good sake batches has been carried out, accompanied by fermentation tests. Since 1906, the yeast thus selected has been distributed as “Kyokai sake yeast” by the Brewing Society of Japan.

One ampule (approximately 10 mL) in the photo contains approximately 20 billion yeast cells. If you ferment one ton of rice using this one ampule for starter culture and then fermentation mash, you can make approximately 1,200 bottles (using 1.8 L bottles) of junmai-shu.

Kyokai sake yeasts are numbered in ascending numerical order according to their launching. Nowadays, K-6, K-7, K-9, K-10, K-11, K-14, and K-1801 are often used. These yeasts are closely related, genotypically. However, each sake has a different aroma and taste. They are used selectively to attain a desired goal regarding the qualities of the sake being produced. It is said that the aroma of ginjo-shu has become especially fine since “Kyokai sake yeast K-7” came into use (isolated in 1946). K-7 features a vigorous fermentation and pronounced aroma. Even nowadays this yeast is still widely used for brewing sake. From toward 1975, “Kyokai sake yeast K-9” has played a major role in the production of ginjo-shu. Its wonderful aroma as well as mild and smooth taste has established the style of ginjo-shu. Recently, “Kyokai sake yeast K-1801” is being used, featuring an apple-like ethyl caproate aroma and a mild taste with low acid production. Unique yeasts bred in the various prefectures are used to make many types of sake, including ginjo-shu.
Shubo (Starter culture)

After the koji making has finished, the next step is to prepare the sake starter culture. Just after the starter culture is prepared, wild yeasts remain in the culture, in addition to desirable sake yeast, like Kyokai sake yeast. While the rice koji is being made, these wild yeasts increase as well. However, some wild yeasts (for example, film yeasts) produce unfavorable components that smell like paint thinner or vinegar, and others stop the process of alcoholic fermentation. For sake brewing, we must use excellent yeast that ferments at a low temperature, generates a great deal of alcohol, and results in sake with a good flavor. The propagation process of selected yeast, shubo, ensures a good fermentation of sake.

What features are necessary for starter culture? First, starter culture should contain a great deal of yeast. Second, starter culture has to have the appropriated level of acidity. An acidic condition helps prevent the increase of bacteria that can spoil the main fermentation. This phenomenon is similar to the process of making pickles, which is a way of storing vegetables in vinegar to prevent their spoilage by bacteria. There are two methods for making the starter culture acidic: using a lactic acid fermentation process, and using lactic acid specially prepared for brewing. The representative method of using a lactic acid fermentation process is called “kimoto (kimoto starter culture).” The representative method of using lactic acid is called “sokuyo (sokuyo starter culture).”

Kimoto

Kimoto is the technique developed in the Edo era (1603 to 1867) for growing yeast using natural microorganisms. The first step in the kimoto process is to put 14 to 15 kg of steamed rice, koji, and water into a tub, called hangiri, at a temperature of 8°C. After a few hours, the rice grains swell with absorbed water. The workers stir the mixture inside of this tub well, every a few hours.

On the next day, they grind the rice using a tool shaped like a paddle, called kai. This grinding operation is called Yamaoroshi. It is very hard work for two or three workers to grind a tub of rice in a cold room, three times a day. After it is well ground, they move the mash into a tank, where it’s kept for 3 days at 6 to 7°C. This period is referred to as utase. Nitrate-reducing bacteria that were in the starter culture gradually change the nitrate in the water to nitrous acid. This nitrous acid suppresses the multiplication of the wild yeasts.

Five or six days after the ingredients were initially put in the tank, the warming of the mash begins. A cask full of hot water is put into the tank, kept for 2 to 3 hours and then removed. This process is repeated at an increasing rate of approximately 1°C per day.

As the temperature rises, the lactic acid bacteria gradually become active and start to produce lactic acid. The combined actions of the lactic acid and nitrous acid cause the film yeast and wild yeast to die off. Then, as the lactic acid increases, the mash becomes so acidic that the nitrate-reducing bacteria also die off, and the remaining nitrous acid is converted.

As the acidity increases further, even the lactic acid bacteria find themselves in an unfavorable environment, and they die off, as well. At this stage, the amounts of sugar and amino acids in the mash have increased, and so the mash is the ideal environment for growing of the sake yeast, which is well able to tolerate acidity.

Therefore, now is the time to add previously cultured sake yeast to the mash. In the past, the natural yeast that was specific to each brewery grew there, or the brewer retained some already fermented starter culture to add to his mash, continuing his established line of yeast. During the last half of the starter culture process, the remaining lactic acid bacteria are killed by the alcohol that is being generated by the yeast. As a result, finally only sake yeast remains in the culture.

Yamahai (Yamahai starter culture): a modified type of kimoto

Some bottlers of sake have Yamahai or Yamahai-Shikomi written on their labels. Yamahai is the abbreviation for yamaoroshi-haishi. This name was chosen to indicate that yamaoroshi, the most arduous work in the kimoto process, had been done away with. In the yamahai method, steamed rice is broken down by koji enzymes, not by the physical effort of the workers using their paddles. This process saves the time, labor, tools, and space needed to grind the rice during the kimoto operation. This method was developed in 1909 by our institute. There is not much difference between the kimoto and yamahai processes, in terms of the final quality of the sake or the character of the yeast used.
**Sokujo**

Kimoto was a very successful technique established by our predecessors in the era when they did not know that sake was made by microorganisms. However, some lactic acid bacteria that would remain in their starter could spoil the sake. These harmful bacteria may multiply if the starter culture-making operation is not appropriately controlled. In the past, it had often happened that a warm winter resulted in contamination of the starter culture by harmful bacteria, and the fermentation mash would be spoiled. The mash can no more properly ferment due to infection than rice or vegetable can grow due to disease. Another consideration involved in the starter culture-making process was that much care and labor was required during the long period of four weeks to create the kimoto.

Then, in 1909 we developed the method to produce starter culture by adding very pure lactic acid (brewing lactic acid) to subdue the growth and activities of microorganisms. Simultaneously the yamahai process was developed. With kimoto, it takes two weeks or so to produce lactic acid by lactic acid bacteria. Using very pure lactic acid saves this period. This method produces starter culture much faster, so it is called sokujo (rapid production of starter culture). Currently, most sake is made through this sokujo process.

**Moromi (Fermentation mash)**

Fermentation mash is prepared by the addition of water, rice koji, and steamed rice to a starter culture, and then actual sake fermentation starts.

The size of a batch of sake manufacture is shown by the weight of the white rice used. A small batch is one of about a hundred kg, and a large batch can be 10 tons or more. Normally, a fermentation tank has a capacity three times the volume of the amount of rice used. If a sake batch is 10 tons or more, a fermentation tank with a capacity of 30 KL or larger is needed to hold the fermentation mash. The standard relationship between the steamed rice and the rice koji in a fermentation tank is 77 (rice) plus 23 (rice koji) (where the white rice is measured in kg), plus 130 liters of water.

The whole vat of fermentation mash is not prepared at once. It is prepared in successive stages, by dividing the total into three portions, prepared over four days. This process of preparing the fermentation mash with gradually increasing three portions is referred to as sandan-jikomi (three-step preparation of fermentation mash). This is done to prevent a delay in the production of alcohol by diluting the yeast too much, and to prevent the growth of unwanted bacteria.

The 1st day is referred to as soe (first addition). The 2nd day is adori (the next day after soe), which is when the workers wait for the yeast to grow. The 3rd day is naka (second addition) and the 4th day is tome (third addition).

Low temperature fermentation is appropriate for brewing sake. The low temperature controls the activity of yeast and allows the alcoholic fermentation to progress steadily, resulting in finer quality and more delicious sake.

Fermentation takes place at 10 to 18°C generally. About one week after the third addition, fermentation becomes active. Then, fermentation settles down after three weeks, when the alcohol has reached 18 to 20 percent.

**Foaming yeast and non-foaming yeast**

Normally, sake yeast produces a layer of foam that covers the surface of the fermentation mash from 4 to 10 days after the third addition. This was a characteristic of sake yeast. However, non-forming yeast was reported independently by NRIB and the Hiroshima Regional Taxation Bureau in 1916.

No foam layer means that brewery workers do not need to clean foam off their tank walls. They also do not need to worry about overflowing foam during active fermentation. In case of non-foam-generating-mash, fermenting tank could accommodate more mash than foam-generating-mash by the volume of form. There are many benefits to using non-foaming yeast, but manufacturers did not consider using it when it was first discovered.

Then, in 1963, the demand for sake exceeded the existing production capacity, and people saw that non-foaming yeast could contribute to increasing production capacity within the same facilities.

The staff at NRIB developed a breeding method of non-forming yeast, and eventually succeeded in obtaining a mutant non-foaming yeast from “Kyokai sake yeast K-7.” In 1971, this mutant yeast was named “Kyokai sake yeast K-701,” and it went into distribution. Now, a great deal of sake is brewed with non-foaming yeast. This research was a real game-changer for the sake industry to find a way “to create” a new yeast, in addition to “to select.”

Then, we continued researching into foam made by yeast, and identified the AWA1 gene that is responsible for forming of yeast. On the basis of this finding, we are now able to grow other non-foaming yeasts, because we can check various yeasts for the presence and expression of the AWA1 gene.
Pressing and finishing

Josō (Pressing)

Pressing is the process used to separate the matured fermentation mash into sake (the liquid) and sake cake (the solid). Sake cakes consist chiefly of the rice, koji and yeast remaining after the fermentation. During this pressing process, it is important to keep the temperature low, avoid too much pressure, and avoid the sake’s contact with the air as much as possible. Sake, as well as other alcoholic beverages, deteriorates in quality through the effect of oxygen in the air. There are various methods to press sake. One method is to put the fermentation mash into a tube-shaped cloth bag called saka-bukuro and hang it so the sake drips out. Another method is to use a pressing device such as a traditional press (fune) or an automatic filter press for sake.

When you use a fune, you lay some cloth bags filled with fermentation mash at the bottom of the fune and then stack more cloth bags on top. Stacking up the cloth bags causes the weight of themselves to press the fermentation mash. The naturally pressed sake drains out of a tap. The first-running sake is cloudy, but as the cloth weave is filled with residual solids it functions as a fine filter so that the later-running sake becomes transparent. The first-running sake is referred to as arabashiri (free run sake). Once the speed of sake being naturally pressed reduces, we use a press. At the top of the fune hydraulic unit is equipped, that presses the fermentation mash by gradually raising the pressure on the cloth bags. The flavor of drained sake changes little by little, depending on the time elapsed and differences in pressure level, even though it is coming from the same run of fermentation mash.

When pressing using an automatic filter press for sake, the fermentation mash pours in between vertical plates to which filtration cloths are attached. High-pressure air is forced into rubber bags attached to the plates. These rubber bags inflate and apply pressure to the fermentation mash from both sides.

Oribiki (Removal of sediment), filtration

Soon after pressing, sake is a cloudy white, as shown in the upper right. The cloudiness is caused by fine particles of yeast, rice, and rice koji. This is referred to as the ori (sediment). Oribiki is the process of removing the sediment from the sake after pressing. The sake yeast in the sediment is still alive after pressing. It can restart fermentation within a certain temperature range, or go into self-digestion (resulting in its death). In addition, the components in sake will be changed over time by the enzyme activities derived from koji and sake yeast. Leaving the sediment in the sake for a long time may increase the amino acids and sugar, causing deterioration of the sake’s quality. Generally, after pressing, sake should be stored at a low temperature. When the sediment sinks, it is removed from the sake. The first removing is generally done five to ten days after pressing. The amount of sediment will depend on each pressing method used. Only a small amount of sediment remains after pressing using an automatic filter press for sake. Therefore, some brewers dismiss the process of sediment removal after using this pressing method. In this case, any remaining sediment is removed by a filtration machine.

Filtration is used to remove fine particles (sediment and microorganisms) suspended in sake through a fine mesh filter. There are different filtration methods specific to respective purposes: filtration to remove sediment, filtration after activated carbon treatment to adjust flavor, and final filtration performed just before bottling.

Activated carbon for brewing is added into sake to adjust flavor. There are a lot of extremely tiny pores on the surface of the activated carbon, which absorb coloring matters, bitter taste and smell constituents. Coloring matters and off-flavor constituents are removed owing to physical properties of activated carbon. Therefore this technique enables us to prevent coloration and over-maturation of sake caused by heat and light. Just after being pressed, the color of sake is light yellow. After activated carbon treatment and filtration, the sake is almost colorless and quite transparent. Whether or not to use the activated carbon and how much is that used are subject to the target quality of the sake.

Hi-ire (Pasteurization)

In pasteurization process, sake is heat-sterilized to assure microbial stability and product quality. Freshly pressed sake has a unique fresh deliciousness. However, the enzymes derived from the koji and sake yeast are still active. Fresh sake is quite unstable in quality. Over time, it is likely to get sweeter and develop an offensive smell, called namahine-ka or mure-ka. These enzymes cannot be removed by sediment removal and filtration. In addition, hiochi bacteria (some kinds of lactic acid bacteria that are tolerant to alcohol) can grow in fresh sake, deteriorating its quality. This is why the sake is
heated to about 60 to 70°C, which kills the *hiochi* bacteria and inactivates the enzymes. This stabilizes the product’s quality.

In general, sake goes through two pasteurization steps. The first pasteurization is performed before storage, and the second one is done just before or after bottling. There are two methods of pasteurization. One is to apply heat to sake by heat exchangers equipped between hoses linking tanks and bottle-fillers. The other is to heat bottles filled with sake.

Usually, heat exchangers are used to pasteurize sake. On the other hand, heating sake in bottles provides so precise temperature control that this method is especially used for *ginjo-shu*. Heating in the bottle prevents loss of the fruity flavor, and so the typical flavor of *ginjo-shu* is well retained.

All the same, there are also non-pasteurized sake brands. A sake stored, bottled, and shipped without any pasteurization is called unpasteurized sake (*nama-zake*). Typically, *nama-zake* is protected from quality degradation by cold storage or special filtration. This lets you enjoy the fresh taste of sake owing to being unpasteurized. In another variation, there is also sake that is pasteurized before storage, but not before bottling. This is referred to as fresh-bottled sake (*namazume-shu*). A sake that is not pasteurized before storage but is pasteurized before bottling is referred to as fresh-stored sake (*namacho-zo-shu*).

**Storage**

After it is first pasteurized, usually sake is stored in a storage tank. In the storage tank, the sake sits quietly and matures. This will increase its good matured different flavor and smoothness from freshly pressed sake. It is important to keep the tank temperature quite constant, to promote stable maturing.

**Blending, adding water**

Blending is the process of mixing sakes from in different tanks. Even if the same rice, *koji* mold, and yeast are used, the components of sake may vary because of the variation in rice treatment and temperature profiles during the *koji* making and fermentation. In order to ship stable quality sake throughout the year, manufacturers blend different runs of sake. Blending is carried out when the sake is moved from storage tanks to as the next filtering and bottling processes.

Water may be added to sake in order to adjust its alcohol content. Just after pressing, sake has relatively high alcohol content, around 18 to 20%. Water is added to reduce alcohol content level to 15 to 16%, which is suitable for drink. The same high quality water as brewing water is used to dilute sake.

On the other hand, there is also sake without being diluted. This is referred to as undiluted sake (*genshu*). In general, *genshu* has a rich taste, but you should be careful not to drink too much! It has a high alcohol content.

**Bottling, shipping**

Bottling is the final process of brewing sake as a commercial product. Particular attention must be paid to the maintenance of a hygienic environment, to prevent contamination by foreign material and microorganisms. Therefore, some breweries clearly separate the bottling area from the manufacturing area where *koji* mold and sake yeast are handled, or place the bottling area in a separate location (or even another building).

Special machines are used for bottling to fill the bottles up to the specified amount. Pasteurization is performed at bottling, except when brewing unpasteurized sake (*nama-shu*) and fresh-bottled sake (*namazume-shu*). When heated sake was bottled, it pasteurizes both the bottles and the sake in the bottle, and the air is pushed out of the bottles by the steam emitted from the sake, thus decreasing the amount of oxygen inside. Therefore, this prevents deterioration by oxidation as well as by bacteria.

After bottling, labels are put on the bottles. The sake is now completed as a commercial product. The labeled sake bottles are packed in cardboard boxes or special plastic crates for shipping.
Enjoying sake

The maturation period and flavor change

**Hiyaoroshi, freshly pressed sake**

Typically, sake is held for maturation in a tank or bottle for six months to a year, and then shipped throughout the year. In general, higher temperature promotes faster maturation. In the autumn, after being stored throughout the summer, sake is moderately mature and has a mild flavor. A specific sake called *hiyaoroshi* is shipped during the autumn. Although there is no legal definition of *hiyaoroshi*, it is a kind of *namazume-shu* that has been pasteurized before storage, and that is not re-pasteurized when bottled and shipped in the autumn.

Some sake is shipped without being aged. Such freshly pressed sake can be found at sake breweries and in liquor shops from the winter to the spring. Generally these fresh, un-matured forms of sake are unpasteurized (*nama-shu*).

**Long aged sake**

Before storage technology was well developed, it was very difficult to retain the flavor of sake at an acceptable level for over a year. Recently, thanks to the development of modern technology and devices of storage, sake with unique flavors obtained after long intentional storage is made. They are what is called long aged sake.

Even if it’s pasteurized, sake stored for a long time changes its color to bright yellow and eventually to amber. This is because the reaction of sugar and amino acids in the sake creates a colored matter called melanoidin. At the same time, the aroma changes to a complex one with nuances of caramel, honey, nuts, and spices. This is believed to be the result of the reaction of sugar and amino acids which combine through the Maillard reaction, as well as from the breakdown of amino acids. The flavor gradually becomes smoother. Due to some increase in bitter-tasting components, the sake develops a complex flavor and rich body, and it has a feeling of expanding volume that is different from the sake before storage.

Well-structured sake like *jumai-shu*, after being stored for a long time, can achieve a deep color, complex flavor, and rich body. Sakes with a delicate taste and aroma, like *ginjo-shu*, are often stored at a low temperature. After long storage, they have a light color, mild flavor, and a light and delicate taste.

Aged sake (*koshu*) is contrasted with new sake, and refers to sake brewed before the last brewing year (brewing year is from July 1st to June 30th of the next year). Among long-term stored sakes, those stored for an extremely long period are referred to as greatly aged sake (*daikoshu, ogoshu*). Sakes stored longer than 5 years are sometimes called treasured sake (*hizo-shu*).

### Off flavors in aged sake (*hine-ka*) versus a matured aroma

In the past, some aromas that developed in sake during storage and distribution were referred to as off flavors of aged sake (*hine-ka*). *Hine-ka* may contain various aromas. If, after a rather short storage and distribution period, the sake smells like *takuan*, a Japanese pickle, then the sake is considered to have deteriorated in quality. On the other hand, if a smell like caramel comes from long aged sake (held for a number of years and even decades), this is called the matured aroma (*jukusei-ka*). This aroma was recognized as a positive feature of long aged sake. However, off flavors and matured aroma were not well distinguished even by sake experts.

Therefore, our institute set about re-defining *hine-ka* as off flavors which are different from matured aroma, and began research into these two aromas. What we discovered is that *hine-ka* chiefly consists of dimethyl trisulfide (DMTS), while the caramel-like smell of matured aroma is related to sotolon, which is as known as the main flavor compound of aged sake.

We went on to research the cause of the *hine-ka* compound, DMTS, and found that yeast creates a precursor of DMTS (DMTS-P1). Also, various brewing conditions influence DMTS formation.

Even now, we are engaged in research into how to reduce DMTS in order to retain sake’s quality for longer periods.
Storing sake
In order to preserve sake’s flavor, it is important to store it appropriately. In this section, we would like to explain how to store sake at home.

Light, high temperatures and oxygen are the enemies of sake. It is particularly the case that if sake is exposed to direct sunlight, high temperatures or sudden temperature changes, the sake’s quality will suffer. Therefore, the principle is to store your sake in a cool, dark place. In addition, be careful and remember that even when a sake bottle is unopened, such strong odors as insecticide and soap can be transferred into the sake.

Make sure you store sake that are labeled “keep refrigerated,” like nama-zake, in a refrigerator all the time. Enzymes are still active in nama-zake, so it will lose quality even faster than draft beer. Sakes other than those labeled “keep refrigerated” should be stored in a cool, dark place. Keep them in their original packages: the paper rolled around the bottle or the cardboard box.

How should we store the once-opened sake? Of course, opened sake should be stored somewhere cool and not exposed to light. But besides that, it will also be negatively affected by the oxygen in the bottle. It is recommended that the opened sake should be drunk as soon as possible.

The mechanism of sake deterioration – the effects of light and temperature
It should be noticed that fermented liquor like sake, beer, and wine deteriorate more readily than distilled liquor like whiskey, shochu and vodka.

Why do these fermented liquors deteriorate easier than distilled liquors? It is because they contain much more such components as sugar and amino acids. These components do not evaporate by distillation. Therefore, they are not included in distilled liquor. Sugar and amino acids are the ingredients that make the characteristic flavor of sake. On the other hand, they can also cause unwanted change of color, aroma and taste.

You may find it hard to believe that light alone could cause deterioration of sake. Yet you know that ultraviolet rays in the light can have remarkable effects, like causing our skin to tan or even burn. It can trigger chemical changes of the components in sake. Therefore, change of color, deterioration of flavor, and increased bitterness are caused.

The pairing of sake with different foods
It goes without saying that sake alone tastes good, but food enhances sake up to the outstandingly delicious level. By experience, we know that simple tasting Japanese foods like boiled tofu (yudofu) go well with sake. Each region has its own liking for tastes of sake ranging from sweet to dry, or from rich to light. Therefore it is well-known that each local sake goes well with its own dishes. In France, the relationship between a particular food and wine is referred to as “le mariage” (the marriage). In general, it is felt that white wine is good to drink with chicken and fish dishes, and red wine is good to drink with lean meat dishes.

There is a lot of information about the pairing of alcoholic beverages and foods, and there is also some understanding of the scientific reasons for these pairings. Below is some information from a research report from a leading Japanese liquor manufacturer: 1) White radish in odon (Japanese hodgepodge) is good with sake, but not good with either red or white wine. Camembert cheese goes well with wine. 2) Good pairing occurs when both the dish and the alcoholic beverages increase in positive flavor, and a pleasant aftertaste is created. Incompatibility results in an increased fishy smell or a bad taste experienced after tasting the dish. 3) Iron in wine accelerates the oxidation of polyunsaturated fatty acids such as the docosahexaenoic acid (DHA) contained in fish and shellfish, and this generates fishy odor compounds.

We are also carrying out the research about the pairing between alcoholic beverages and foods. We found that sulfurous acid in wine causes the fishy odor and bitterness from DHA contained in dried cuttlefish. If you try dried cuttlefish together with white wine, you will probably perceive a strong fishy smell. However, if you try it with sake, you may not perceive that smell much, or at all. This phenomenon occurs because sake does not contain sulfurous acid or similar compounds. Thus, we have shown the scientific reason why sake goes well with the fish and shellfish that are the epitome of Japanese cuisine.

The Story of Sake
Enjoying sake

The odor that comes from exposure to light is referred to as light struck smell (nikko-shu). It should be noticed that not only sunlight, but also fluorescent lights, can cause slow deterioration of sake.

We also researched the relationship between the color of sake bottles and the effects of light. There are many kinds of light with different wavelengths. Humans can see light in the wavelengths from violet (approximately 380nm) to red (up to 780nm). Ultraviolet (UV) at wavelengths of 400nm or lower causes chemical reactions of some ingredients in sake.

The graph below shows the light-transmission characteristics of different color glass bottles. Brown bottles do not transmit light waves below the 450nm range that includes UV. Transparent (clear) bottles, blue bottles, and moss green bottles do transmit UV light. However, cans and paper-packaging do not transmit almost any UV light so that their contents are not affected by light. Lots of sake and beer are sold in brown bottles because they do not transmit UV rays.

On the other hand, high temperature causes the initiation of a browning reaction called the Maillard reaction in sake that contains a lot of sugar and amino acids; this reaction causes color changes and a sweet and toasted smell. Higher temperature enhances other reactions, and cause earlier deterioration.

Sake is made by means of the established technique that has been developed by sake brewers. It is delivered to customers at the high level of quality that sake-drinkers expect. The background of sake technology has been elucidated by research institutions, including ours. If you associated sake with its fruition of many years of scientific and technological development, you could find a much more distinguished taste of sake than you ever experienced.

Alcohol and the J-curve effect

From ancient times, it has been said that alcoholic beverage is the best of all medicines, and it has been believed that drinking appropriate amounts will contribute to maintaining good health. On the other hand, imbibing large amounts of alcohol can be hazardous as it factors into the development of various diseases, such as liver damage, cancer, and brain dysfunction. A variety of investigations are being carried out concerning drinking and health. There has been a report that found that people who drink alcoholic beverage in appropriate amounts have a lower death rate than those who do not drink at all and also lower than those who drink too much. The graph showing the amount of alcohol consumed relative to the death rate is known as the J-curve effect from the shape of the curve. However, this J-curve effect had not been tested by physiological experimentation, and there was no clear scientific basis for it.

Therefore, we performed an experiment in which it gave small amounts of alcohol to animals, and investigated the effects on their health to verify the J-curve effect. Mice and rats who received low concentrations (1%) of alcohol were resistant to aging, as shown in the graphs below, and were not likely to suffer liver damage. These experiments suggested that a small amount of alcohol intake can be good for health. On the other hand, as the shape of the J-curve shows, excessive intake of alcohol is a factor disposing people to various diseases. Therefore, please remember that a “small amount of alcohol” is good for health is not the same as alcohol is good for health. Also, note that this result does not mean that non-drinkers should be forced to drink alcohol.

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March 2017