Aroma development during barrel aging

UNIQUE CHARACTER | The craft beer movement has inspired craft brewers all over the world to experiment and play with new approaches to beer production. Among these approaches is barrel aging, which has risen in importance and now is considered part of the standard practice in the industry. Barrel aging provides a means for producing unique character in beer, rooted in the distinctive aromas and flavors formed over time using this method. However, to make this type of beer, the brewer must possess a certain amount of knowledge on how pre-treated or previously occupied barrels can change the aroma and texture of beer. This article explains the factors at play during barrel aging and the technical aspects of aging beer on wood to modify and generate desirable aromas and flavors.

IN ORDER TO SUCCESSFULLY mature beer in wooden barrels – that is, to age it – many different factors come into play, which when combined, can produce a mature beer characterized by complex aromas and flavors and a correspondingly striking color.

Direct influences on the formation of aromas and flavors in beer

Selecting a wooden barrel

Choosing a suitable wooden barrel for aging beer is very important. Particular consideration should be given to the ratio of volume to surface area because the greater the contact area is, the more influence the barrel has on the development of the beer. This means that large barrels have less influence while smaller barrels create a much more intense sensory profile. The degree of "toasting" of the wood is an additional influence that has to be taken into account. The same is true if the wooden barrel has hitherto been used to store spirits, wine, a different beer or has never been occupied. These factors have a major impact on the final aroma and flavor of the beer. Potential barrels for aging beer include those which previously housed whisk(e)y, bourbon, scotch, cognac, armagnac, rum, tequila, gin, cachaça, sherry, port, madeira, red wine, white wine, sweet wine or extremely strong beer.

Using wood chips

The utilization of wood chips in place of a wooden barrel also affects how beer aroma and flavor develops. The use of wood chips in wine production was prohibited until 2006. Since then, wood chips are permissible, but the wine may not be advertised as "barrique aged" or similar. Caution should be exercised when making statements about barrel-aged beers as the legal situation has yet to be fully clarified.

The duration of barrel aging

The duration of maturation in a barrel obviously plays a key role in the formation of the aromas and flavors in beer as well. The duration of maturation on wood can vary greatly depending on the type of barrel. Several guidelines are listed below for general orientation:

- A time span from a few days to up to three years;
- shorter times for new barrels and bourbon barrels;
- for barrels in which other spirits have been stored: the intensity of the spirit is a major factor.

The period of maturation is usually longest for beer aged in wine barrels since *Brettanomyces* yeast as well as lactic acid and acetic acid bacteria may be present in the barrels. In this situation, the decision should be made as to whether an overt contribution by these microorganisms is desired in the final beer flavor or whether the influence should simply be more "random".

Blending and filling

Anyone who is under the impression that creating an aged product is possible just by following these few points will be disap-

Fig. 1 The staves are deliberately left outside to dry in the air, exposed to the elements

Author: Michael Eder, Brewmaster and Head of Production, Doemens Academy, Gräfelfing, Germany

pointed to find out that the work to develop the aroma and flavor of the beer is just now beginning. After the beer leaves the barrel, the next steps of blending and filling can also strongly impact the aroma and flavor profile of the finished product.

Achieving the right blend is the key to the balanced sensory properties of barrel-aged beers. Different barrels, degrees of aging and fresh beer can be combined in a seemingly arbitrary way to obtain the desired aromas and flavors. In the barrel, beer loses a major part of the CO_2 formed during fermentation and begins exhibiting notes of oxidation. There are three possible strategies for filling the beer:

- Fill the beer without further treatment;
- elevate the carbonation levels in a tank;
- allow secondary fermentation to occur in the bottle.

The right beer for the right barrel

Countless options are available when it comes to choosing which beer is actually suitable for barrel aging. In principle, almost every beer can be matured in a barrel – but experience has shown that stronger beers with a moderate hop aroma tend to fare better than beers lower in alcohol. Naturally, there are some quite successful examples which do not follow this general tendency.

The role of wooden barrels throughout history

Historically, there is a very long tradition of storing and transporting beverages in wooden barrels. The first vessels made of wood were carved from tree trunks (around 1000 BC). The Celts are credited with constructing barrels from wooden staves (approximately 300 BC), although the first mention of this type of barrel dates back to Roman sources (50 BC).

The ancient civilizations of the Mediterranean, however, used clay amphora for storing wine. The smaller version of the barrique (225 liters) is a 15th century invention (for ship voyages during the Age of Exploration) so that the barrels could be moved by men without further assistance. Starting in 1866, such barrels were recognized as a unit of measure in the overseas wine trade.

One should take note of the fact that at least initially these barrels were not chosen for qualitative reasons but instead were utilized to transport liquids – i.e. beverages, and this despite the fact that transport had a massive impact on the quality of the contents of the barrels.

The development of the barrique for winemaking

Oloroso (= scented) was the first wine exported from Jerez to England. The hot southern climate and movement on ships resulted in micro-oxidation and aromas with notes of wood. The same applies to port wine.

Rotspon is a German word for red wine that was bought in France during the Hanseatic period and transported to Germany in wooden barrels (as early as the 13th century). Some wine merchants and vintners from Bordeaux no longer recognized their own wines after the wine had been transported and stored in wooden barrels.

At the beginning of the 19th century, the Estournel winery was one of the first to discover the positive influence of transporting wine in wooden barrels. Unsold wine from India was labeled “R” (return) and sent back to the country to be sold for a high price. Other top wineries in Bordeaux then began using 225-liter barriques, and bodegas in the Rioja region also adopted this concept.

In the 1970s, it was discovered that the use of new, toasted oak brought about profound changes in wine. Research has been carried out in this area since the 1980s, and red and white wines aged in wooden barrels are popular around the world.

The difference between traditional wine barrels and barriques

How does a traditional wooden wine barrel differ from a barrique? Traditional wooden barrels should maintain the flavor of the wine without affecting the flavor of the product. This is accomplished by subjecting the barrels to alternating treatments of hydrochloric acid and sodium hydroxide (caustic soda). This process leaches tannins and aroma compounds from the wood. Barrique barrels, in contrast, are toasted rather than treated with acid and caustic.

The effects of storage in oak barrels

Storage in oak barrels affects the product by contributing various aromas, oxygen and tannins (ellagitannins) to the formation of the sensory properties of the wine. The oxygen primarily increases the oxidation notes in the wine, thereby accelerating the aging process. The yeast in the wine (or beer) traps oxygen. White wines aged on the yeast are referred to as sur lie wines.

As mentioned previously, the oxidative effect is stronger in smaller barrels due to the higher ratio of inner surface area to volume. This, in turn, results in a greater exchange of substances (oxygen, aromas and tannins).

Wood selection and treatment

Desirable aromas found in barrel-aged beer include coconut, vanilla, honey, caramel, almond/marzipan, hazelnut, cinnamon, clove, chocolate, coffee, mocha, smoke and pepper. Here, the choice of wood has a decisive influence on the aromas that may develop. The density of the annual rings in the wood provides information about the growth rate of the tree throughout its life. Slower growing types of wood have a higher aroma potential than rapidly growing oak.

Most barrel wood is made from 100 to 150-year-old trees. The logs are cut into quarters from which the wooden staves are sawn (fig. 1) or traditionally split with an axe. The staves are then dried (to 14-16 % moisture) for two to three years, ideally in the open air. The wood is deliberately exposed to the natural elements, for example, rainwater helps wash out tannins. Enzymes and microorganisms in the wood bring about positive changes, which in turn are important for the formation of flavors during the toasting process. Wood artificially dried in chambers is green, dull and resinous in appearance.

Fig. 2 The previous contents of the barrel, e.g. port barrels as shown here, play an important role in the formation of aroma

The quality and types of wood

The quality of the wood is determined by its provenance, the prevailing climate, the type of soil, the water supply, the age of the trees and the nutrient supply:

- Limousin (rich and moist soils) = large-pored structure;
- Vosges (dry clay soils) = small-pored structure.

The main types of oak (*Quercus*) wood are:

- French oak (*Quercus robur*) grows slowly. This wood is split to reduce it in size; it has a higher tannin content (approx. 10 %) and is characterized by a strong aroma;
- American white oak (*Quercus alba*) is a fast-growing oak species with a lower tannin content (2 %). The oak can be sawn. Its aroma profile includes coconut, vanilla and roasted notes;
- Russian oak (*Quercus hartwissiana*) possesses a scent which is reminiscent of cedar. The aroma development is less aggressive than French oak, but with a creamier note;
- Japanese oak (*Mizunara, Quercus magnolica*).

Why choose oak for barrel-aging?

Oak wood has no veins of resin (it is solid wood). Therefore, no unwanted resins are transferred to the product and as a secondary effect, the wood becomes more porous (micro-oxidation). In addition, oak is flexible, very durable and impacts aroma formation in a positive manner.

Barrel construction

The staves are first joined together and then ground down to create rounded corners with a slightly wider center section. This step is important in order to achieve a precise form.

The staves are then connected to a head piece on the floor. When they are all connected, they extend up vertically in a circle. The staves are then steamed to make them pliable enough to be bent and connected at the other end. This is accomplished by exposing them to steam at 95 °C for about 15 minutes.

To attach the other end of the barrel, the staves are pulled together with a winch and are held in place with a provisional iron hoop. After toasting, the heads and staves are pegged, and iron hoops are affixed to maintain the shape of the barrel.

Toasting and charring barrels

When toasting wooden barrels, the amount of time and the intensity of the fire determine the degree of toasting:

- 5 to 10 min, weak toast = unusable;
- 10 to 15 min, medium toast = wine;
- 15 to 20 min, strong toast = spirits.

The temperature and time are primarily dependent on the type of oak and the desired sensory characteristics. Toasting takes place over an open oak wood fire before the barrel heads are inserted. Temperatures reach approx. 200-250 °C on the surface of the wood.

The main goals of toasting are the thermal decomposition of green, astringent, high-molecular weight tannins (ellagitannin, gallotannin, coumarin) and resins on the surface of the wood. Likewise, undesirable aroma compounds are broken down and lignin is degraded, resulting in the formation of desirable aroma compounds (vanillin, eugenol, guaiacol).

The composition of wood

Wood is made up of three (odorless and tasteless) compounds:

- Cellulose (40-55 %): a long-chain

macromolecule consisting of sugar units;

- hemicellulose (20-30 %): a short-chain, branched macromolecule made up of sugar, serving a structural function;
- lignin (20-30 %): consists of a group of phenolic molecules and assembled into a three-dimensional, amorphous network.

The transformation of substances in wood during toasting

Toasting and the subsequent extinguishing process result in the formation of a charcoal layer, approximately two to four millimeters thick, inside the barrel. This layer later acts as an activated carbon filter, removing unwanted aromas and flavors such as volatile organic sulfur compounds from the beverage.

When roasting or toasting oak barrels, hemicellulose is broken down into smaller sugar units and caramelized, which contributes to sweetness and color. Sugar molecules can then be further degraded to furan derivatives such as furfural and 5-hydroxymethylfurfural (having the aromas of almonds, caramel and toasted bread). Furan derivatives on their own are rather negative in terms of their sensory impression but are considered positive in combination with lactones.

The formation of aromas during toasting

The thermal degradation of hemicelluloses creates furan products from the Maillard reaction such as furfural with its caramel and marzipan notes and 5-hydroxymethylfurfural.

About 20 to 30 percent (by dry weight) of wood is lignin, which is made up of various phenol molecules. Lignin is the source of a number of aromatic aldehydes formed through the thermal degradation of wood: vanillin is a phenolic aldehyde with a vanilla-like fragrance, while syringaldehyde is more reminiscent of forest berries. Other aromas that arise from lignin during toasting are volatile phenols, such as eugenol, which gives a clove-like impression and can further be converted into vanillin, or acetovanillon and guaiacol, which contribute more of a smoky note and may also be further converted to vanillin.

Fig. 3 Whisky barrels impart alcoholic aromas to beer and notes similar to grappa

The whiskey or *Quercus lactone* is a ring-shaped ester and gets its trivial name from the fact that this compound was hardly known prior to the study of the compounds contributing to the sensory profile of whisky. The aroma of this lactone is reminiscent of coconut and is a defining substance in the flavor imparted by oak. American oak contains up to 20 times more oak lactone than European oak. This substance is easily extracted and is mostly found in new barrique barrels. Lactones with eight to nine carbon atoms are characterized by coconut-like flavors, while those with ten to twelve carbon atoms tend to exhibit fruit flavors such as apricot, peach and mango. The cis-whiskey lactone possesses a significantly stronger aroma than the trans-whiskey lactone.

Ionones are yet another class of aroma compounds found in oak. They are formed through the degradation of carotenoids in the wood. Ionone is perceived as a range of aromas, from cedar wood and violet or raspberry to fresh hay. Carotenoids are odorless pigments which are yellowish to reddish in color. When tannins are degraded, the astringent gallotannins and ellagitannins are converted to simple (non-astringent) phenols that can evoke woody and even smoky aromas.

The sensory effects of wood on beer

Most of the experiments and the practical experience concerning the transfer of compounds in wood are related to wine and spirits. The following can be used as descriptors for the common sensory impressions in beer: vanilla, smoke, burnt, spice (clove), phenolic/peat, coconut, caramel and creamy.

Naturally, the contents of the barrel prior to its use for aging beer have an important effect on the aroma (fig. 2). With wine barrels, a fruity, wine-like aroma and additional microflora can be expected. Red wine barrels usually contribute pleasant berry notes and a slightly reddish color. Depending on the variety of grapes in the white wine, it may infuse the beer with notes characteristic of the wine; for example, Chardonnay imparts tropical fruit, peaches and roses.

Whisky barrels (fig. 3), on the other hand, tend to lend more alcoholic flavors and grappa-like notes and, of course, whisky flavors to beer. Aging in Calvados barrels generally results in a fresh apple or cider aroma.

Since oxygen uptake cannot be avoided, it can also strongly influence the sensory profile of the beer. A positive aspect of oxidation is that the hop aroma becomes milder, thus boosting the malt aroma. Sherry-like flavors often arise as a result, making many beers seem more complex. On the other hand, oxygen can have a negative influence as well, such as the development of acetic acid or an increase in the cardboard flavor, depending on the type of microorganisms present.

Microorganisms, whether desirable or not and which influence beer character, include *Lactobacillus, Pediococcus, Brettanomyces, Kloeckera apiculata, Acetobacter* and wild yeast strains.

The development of barrel-aging beers

In the early 1990s, the Chicago Beer Society made its first attempts at aging beer in wooden casks. The Goose Island Brewery's Bourbon County Stout was the first commercial example of a barrel-aged beer. In 1995, this beer was first "commended" at the Great American Beer Festival (GABF), and in 1998, the Imperial Eclipse Stout won for the first time at the GABF (experimental category). The barrel-aged beer category was launched in 2002 and recorded 26 registrations. The first Festival of Barrel Aged Beer took place in 2003. In 2012 there were 197 registrations at the GABF in four different categories and 225 registrations, also in four categories, at the World Beer Cup. The wood and barrel-aged strong beer category had the most entries after IPA with 92.

However, it is also true that good flavor is very difficult to plan, since a large number of factors must come together perfectly. The most experimental brewers have already recognized this and have modified their barrel aging projects accordingly.

For many successful producers of this type of beer, it is a matter of course to accept that a consistently high quality is only possible through a significant amount of blending from different barrels. However, a large number of barrels can be chalked up as "total failures". Nevertheless, the number of barrel-aged beers continues to increase and will find ever more beer lovers not only overseas but also in our Germany. ■