Required reading: The chemistry of beer aging

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There isn't a ton of academic literature on beer aging; unfortunately, most of the scholarly work out there seems to benefit the wine-os. (Cue the beer-versus-wine fight where we all throw corks at each other.) A healthy compendium of brewing studies exists (trying to kill a few hours?)

Check out the archives of the Belgian Journal of Brewing and Biotechnology, but it doesn't seem that too many scientists are keen on studying beer in the bottle.

Still, there are a few golden nuggets out there, and some of the most important beer research is from of Belgian scientist Bart Vanderhaegen.

Vanderhaegen's notable works were completed in the early 2000s during turns as a scholar and consultant at the beer think-tank Centre for Malting and Brewing Science, a research arm of the Katholieke Universiteit Leuven, just east of Brussels. Since 2006, he's been a brewing scientist at Anheuser-Busch InBev; as of this summer, he's handling quality compliance for Hoegaarden.

Vanderhaegen's authored several studies on beer and brewing, but every cellar enthusiast should familiarize themselves with his 2005 publication, "**The Chemistry of Beer Aging: A Critical Review**." (This link will take you to a PDF of the article.) The report sums up brewing scientists' knowledge on the chemical origins and causes of "aging flavors" in beer (particularly the cardboardy (E)-2-nonenal flavor) and touches on the relationship between those flavors and the brewing process.

Vanderhaegen starts off by crediting a 1977 report as the most thorough—but certainly not always applicable—mapping of aging flavors (see chart, right). That study offered up a lot of the information we cellarfolk just call the basics: Over time, bitterness decreases, sweetness grows, stale cardboardiness sneaks up on you, and ribes—what that study's authors call black currant/catty notes—increase quickly, then fall nearly just as fast. But Vanderhaegen regards this study as a "simplification of the sensory changes during storage"—this isn't hard-and-fast stuff, because, as he goes on to explain, these changes vary according to several chemical processes.

Vanderhagen walks through the various chemical changes that can occur in beer aging—both the formation of compounds like the cardboard, stale-tasting (E)-2-nonenal and honeylike phenyl-acetaldehyde, and the degradation of others like esters and hops' bitter alpha acids—then launches into why these things happen.

"The constituents of freshly bottled beer are not in chemical equilibrium," he says. "Thermodynamically, a bottle of beer is a closed system and will thus strive to reach a status of minimal energy and maximal entropy. Consequently, molecules are subjected to many reactions during storage, which eventually determine the type of the aging characteristics of beer."

The author goes on to detail the causes and effects of many chemical reactions happening in your beer bottle: The drama of reactive oxygen species, the degradation of amino and hop acids,

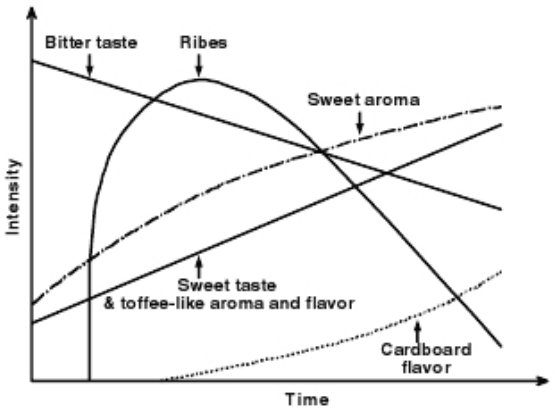

Fig. 1. Sensory changes during beer aging according to Dalgliesh (1977).

the trigger of (E)-2-nonenal "potentials," the Maillard reactions that yield bready / sweet / vinous notes, and more. It's heady stuff, but geeks will dig it.

Of course, none of these reactions (and thus, none of the aging characteristics they produce) are the same in every beer, because beer styles, ingredients, brewing technique and storage vary. And Vanderhaegen intended this summary to be used for re-tooling the brewing process to avoid staleness, not beer cellaring; in 2005, the American craft beer boom was still getting its sea legs, and beer collectors were few and far between. But it's cool to use this information to guess what might happen to the bottles in your cellar, or figure out why a beer tastes like a box.

Vanderhaegen's second must-read is 2006's "**Aging Characteristics of Different Beer Types**," a study that puts the previous article's research to work. Here, Vanderhaegen aged eight commercial Belgian beers—three lagers, two "dark ales" and three high-ABV ales—for one year in the dark at 20 degrees C (that's 68 degrees F), and measured the changes in their concentration of 15 compounds at least four times throughout the aging period. A 10-person tasting panel evaluated changes in sherry, cardboard, solvent, old hops, red fruit and caramel flavors.

Among several noteworthy results, the most interesting finding was a difference in the very nature of aging flavors between the lagers and heavier, darker ales.

In all eight beers, fruity yeast esters decreased, which Vanderhaegen says decreases the intensity of the beer's "background" flavor and increases a drinker's perception of stale flavors. But the sensory tests of the lagers yielded much less significant flavor development than the ales, which Vanderhaegen credits to increased Maillard reactions, which yield burnt, caramel and sherry flavors.

"The Maillard reaction is probably responsible for the gradual diacetyl increase in the eight beers. Formation of this compound is again greater in beers with a dark colour or high alcohol content," says the author. "Consequently, dark beers and high alcoholic beers must contain many Maillard intermediates (e.g., furfuryl alcohol, α-dicarbonyl compounds), which are reactive substrates for aging reactions and many different (off) flavours."

The formation of linear aldehydes, ester formation, ester degradation, acetal formation, etherification and the degradation of hop bitter compounds were also linked to the flavor changes in the darker brews.

Again, Vandehaegen's work was never intended for beer hobbyists, but it seems that he caught a whiff of the beer-aging trend back in '05. Citing a 2002 study by Stephenson & Bamforth, the author mentions, "Indeed, a study with consumer trials pointed out that again flavours are not always regarded as off-flavours," He's a quality-control guy, but we hope he's gotten to find the love in a perfectly oxidized English-style old ale since then.