EXTENDED FLAVOR NOTES: SOME PRESENTED AT THE 25TH GABF COMPETITION -2006
SOME FLAVORS FOUND IN BEER: ORIGINS, DESCRIPTORS, CONTROL, LEVELS.

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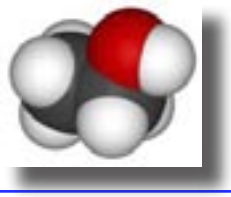
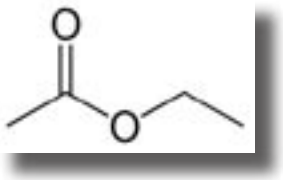
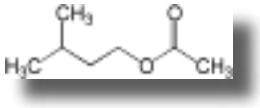
Flavor/Specifics/Examples	Descriptors/Information/Thresholds	Comments and Details of Controls
Alcohol (Ethanol) CH_3CH_2OH or C_2H_5OH Aka: Ethyl alcohol, grain alcohol, EtOH 	Alcoholic, warming. High threshold for this alcohol at 14,000 ppm (1.4% by weight). From glycolysis (Pyruvate conversion to Acetaldehyde and reduction to Ethanol.)	Control of ethanol production:- Original gravity of wort. Fermentable sugars in wort. End fermentation (rack-off timing and cooling). Control through understanding ALL parameters of yeast growth!
Higher (Fusel) alcohols As many as 40-50 distinct fusel alcohols (oils) in beer. The synthesis of fusel alcohols in beer fermentation is linked to the assimilation of the nitrogen sources by yeast and therefore, typically the consumption and production of amino acids.	Alcoholic, spicy, vinous, pungent. Flavor thresholds vary from 50-800 ppm depending upon the specific alcohol. Together with the esters and ethanol the higher alcohols form the "alcoholic" flavor of beer. n-propanol and 2-methyl-propanol said to cause "rough" flavors and harshness to the beer. Fusels - butyl, amyl and isoamyl alcohols said to contribute a general warming sensation in the mouth. A specific example of a fusel compound is 2-phenylethanol (threshold 40-75 ppm) with "Rose-honey-like" odor and taste. This chemical is said to be a "base" component of lagers.	Any conditions that stimulate yeast growth will stimulate fusel alcohol production:- Yeast strain dependent. Temperature dependent. Aeration (oxygen) content of wort. Degree of agitation. Lipid content of wort. FAN (free amino nitrogen) levels. Trub (carry over – fatty compounds). pH.
Esters 90 plus Esters in beer! Specific examples:- Ethyl Acetate, $[CH_3COOC_2H_5]$.  iso-Amyl Acetate, $[CH_3COOCH_2$-$CH_2CH(CH_3)_2]$ 3-methyl-1butyl acetate.  Ethyl Hexanoate (ethyl caproate), $[CH_3CH_2$-O-CO-$CH_2CH_2CH_2CH_2CH_3]$	Formed via reactions of alcohols (ethanol and fusels) and acids (AcylCoA compounds). Catalyzed by specific enzymes called acyl-alcohol transferases or esterases. Formed late in fermentation. Ethanol plus acetylCoA (acetic acid). Aromatic, solventy (nail varnish remover), fruity. Most common ester in beer, typically found at 10-50 ppm. Accounts for upto 1/3rd of the esters in beer. Flavor threshold: 30-50 ppm. (varies with beer). 3-methylbutanol plus AcetylCoA. Aromatic, fruity, banana (pear drops). Found in Bavarian wheat beers. Levels in beer at 0.5-1.5 ppm. (higher in the wheat beers). Threshold at about 2 ppm. Ethanol plus hexanoic acid. Estery, apple (ripe-fresh), aniseed. Produced by yeast during fermentation, especially with low oxygen level. Levels in beer 0.07-0.5 ppm. (varies with the beer). Threshold at 0.2 ppm (reported low, 0.005 ppm in water).	Controls for ester formation:- Yeast strain dependent (ester levels and the actual spectrum of esters formed). Higher fermentation temperature – more esters. High yeast pitching rates – less yeast growth/less esters. Low FAN (plus high sugar levels) can lower ester production. Low wort aeration (low oxygen) raises ester formation. High Plato worts (above 16 ^{0}P). give increased esters. An issue with high-gravity fermentation! Some works suggest that for lagers the level of ethyl acetate should be no more than 5mg/L (ppm).

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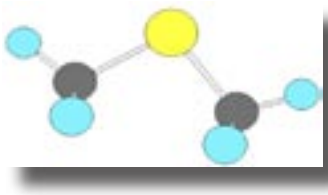
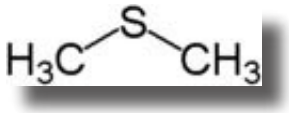
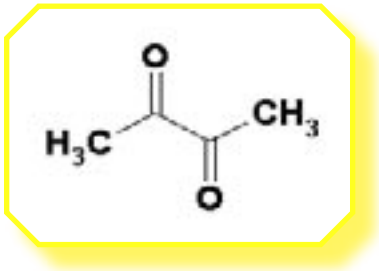
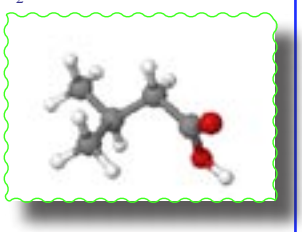
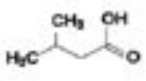
Dimethyl Sulfide (DMS), [CH_3-S-CH_3] [aka: Thiopropane, methyl thiomethane. A thioether: C-S-C] In lager beer the presence of phenyl ethanol (roses or floral notes -see Fusels) has been shown to mask DMS character.  	Malt, veggie, sweetcorn/creamed corn, tomato/tomato juice, oysters (ocean-spray). From malt and precursors-esp., methylmethionine (SMM). Also from wort spoiling bacteria (*Obesumbacterium proteus*). Some wild yeast produce DMS. Sometimes from tainted CO_2. [One source of CO_2 used in the smaller breweries is from corn fermentation!! – unless scrubbed clean, DMS, and also sometimes H_2S, may taint the finished carbonated beer.] Levels in beer 5-100 ppb. Threshold 80 ppb.	A vigorous wort boil converts DMS precursors (SMM and DMSO). Simmering or short boil leaves the precursor – Need a vigorous boil – at least 1.5 hours! Need 8% evaporation rate per hour (or at least 5%/hr). Avoid extended whirlpool stand times or long cooling cycles. (Typically keep entire process to 2 hours total as a maximum.) SMM and DMSO are left behind even with a good boil. If these sit long enough under hot conditions they will convert to above threshold levels of DMS. If excessive DMS is caused by microbial contamination. Sterile sample each brew. For checking CO_2 - bubble the gas through water and smell/taste it!
Diacetyl (a diketone), [$CH_3COCOCH_3$] [aka: butanedione, 2,3 butanedione]  A full review on Diacetyl can be found at www.alcbevtesting.com on the Flavor Corner page.	First noticed as a a roundness ("oily slickness") on the palate. Taste: Butter or butterscotch, movie popcorn, From yeast fermentation or by spoilage bacteria. Levels in beer 8-600 ppb. A desired flavor note in some English ales. Threshold (varies with beer) but typically 80 ppb. Diacetyl is formed outside of the yeast cell. Its precursor (an intermediate metabolite in amino acid metabolism) is excreted into the surrounding wort and is spontaneously converted to diacetyl. Reaction enhanced by low pH and by increased temperature.	Control of diacetyl production and final levels in beer:- During maturation, yeast reduces diacetyl in the medium to less flavor active compounds acetoin (threshold 17 ppm) and ultimately to 2,3-butanediol. The amount of diacetyl produced depends upon fermentation conditions (wort nitrogen levels, pH and temperature). You can therefore CONTROL this through careful attention to the brewing parameters! Limit the amount of precursor (alpha acetolactate) by:- lower temperatures of fermentation; by good yeast growth (healthy yeast); and by adequate aeration. Accelerate the conversion of precursor to diacetyl by performing a "Diacetyl rest" at elevated temperatures before cooling the fermented beer. If yeast are healthy and in sufficient concentration diacetyl will be reduced. Run Diacetyl Tests!
Isovaleric acid (3-methyl butyric acid) $(CH_3)_2CHCH_2CO_2H$ 	From use of old, stale, cheesy hops. Rancid, stale-cheesy, sweaty, fecal, putrid, stale hops Levels in beer -typical: 0.1-2 ppm Threshold 0.1-1.5 ppm	Avoid old/aged hops unless making specific Belgian style beers that call for the preservative and bittering qualities but not the fresh aromatics of hops. 

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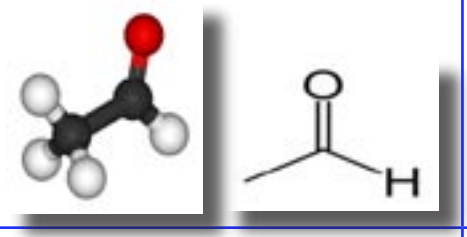
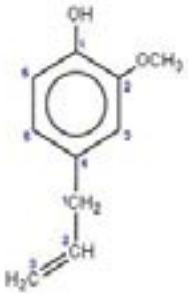
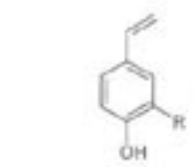
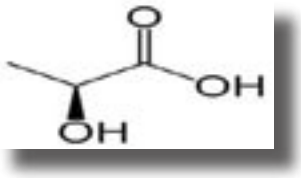
Acetaldehyde [CH_3CHO] [aka: Ethanal] The most important aldehyde of beer, formed as a metabolic branch point in the pathway leading from carbohydrate to ethanol; immediate precursor of ethanol in the metabolic pathway. Its level varies during fermentation and ageing and is usually in the range (in beers) 2-20 mg/L. More toxic than ethanol and a cause of hangovers. 	Green apples, (Bruised Apples) Cut Grass, Avocado, Green leaves (Florist's shop), Melon, Pumpkin. From fermentation or beer spoilage organisms and from oxidation in the finished beer. [E.g., *Zymomonas* in cask-conditioned beer – also produce H_2S). Levels in beer 2-15 ppm. Threshold (ales) 25 ppm. Also cited at 5- 17 ppm. Common note in fresh (green) beer. Possibly higher in wood-aged beer due to complex oxidation-reduction chemistries in the wood.	Acetaldehyde overproduction associated with; yeast strain (yeast strain dependent), poor condition yeast, and with elevated wort oxygen levels. Can be elevated at higher temperature of fermentation (also in high gravity worts when conditions do not permit optimal growth and metabolism of the yeast). High (supersaturated) levels of dissolved CO_2 during fermentation retards yeast growth (acetaldehyde not converted to ethanol) e.g., via back-pressure on tanks. Premature separation of yeast from fermented wort does not allow reutilization of excreted acetaldehyde associated with the latter stages of fermentation. Interacts with sulfites; reduces flavor impact.
Eugenol (4-allyl guaiacol) [A benzene ring plus the $CH_2CH=CH_2$ functional group] Extracted from clove oil and cinnamon. USED AS A SENSORY FLAVOR TO MIMIC NATURALLY PRODUCED 4-VINYL GUAIACOL PRESENT IN WHEAT BEERS.  4-Vinylguaiacol (VG) has $CH=CH_2$ on the 4 ring position [see figure in right column for structures of VG and 4-Vinylphenol (VP)].	Clove-like spicy, phenolic notes. Spicy pungent taste. [Eugenol *has* been found in beer but not usually a flavor component and not formed by yeast activity.] The related 4-vinyl guaiacol and 4 vinylphenol compounds are formed by certain yeast strains (POF+) and wild yeast strains. The precursors are ferulic acid (for VG) and p-coumaric acid (for VP) from malt. (Produced by enzymatic decarboxylation or thermal decomposition of the precursors, esp., the ferulic acid [FA]). Should only be noticeable in wheat beer styles; Belgian White beers, German Rauch beers and Weizen beers. **Thresholds** reported for 4VP at 200 ppb and 4VG at 300 ppb. **Levels**: in Belgian White beers (4VP at ca. 260 ppb and 4VG at ca. 730 ppb - both compounds much higher in Blond specialty beers.	*If not making a wheat beer avoid wheat beer yeasts and wild yeasts.* Controls - levels of VP & VG production:- Yeast strain choice. Control precursor release during mashing. FA release optimal at pH5.8. Barley malt varieties show variations in precursor release. Wort boil times - increases in VG. New work showing aspects of "ferulic acid rests".  R = H: 4-vinylphenol (4VP) R = OMe: 4-vinylguaiacol (4VG)
Trans-2-nonenal (T-2-N), (E)-2-Nonen-1-al, (E)-2-nonenal. $CH_3(CH_2)_5CH=CHCHO$ (aldehyde). Oxidation product of lipids (autooxidation or enzymatic via lipooxygenase) derived from barley.	The so-called "Staling aldehyde" Penetrating, fatty, waxy, wet cardboard, papery, lipstick (even fresh, fruity, melon). Threshold as low as 0.7 parts per billion (or 0.007 parts per trillion!) Fresh beer should have less than 0.05 ppb.	Complex chemistry involved but associated with oxidation of beer. Subject of much recent researches. Keep oxygen to minimal levels (as low as or lower than 100 ppb). Low pH in final product and higher SO_2 levels lower the formation of T-2-N. Warmer storage of beer increases T-2-N.
Sour (Acidic): Lactic [2-hydroxypropanoic acid, milk acid]. $CH_3CHOHCOOH$ 	Sour, sour milk, yoghurt. No odor (non-volatile) - better training compound than acetic. Lactic also is "drier" than acetic. Threshold as high as 170-180 ppm Tends to flatten - make duller the beer flavor/mouthfeel before the sourness is felt.	From lactic acid bacteria/pediococcus, acidulation - acid malts, contaminants or part of Belgian-style sour-wood aging. Contamination in cold part of process. Look for dead legs, Check hoses, Inspect the wort chiller. Pay attention to bottling lines.