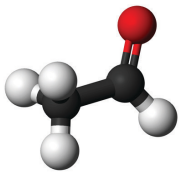
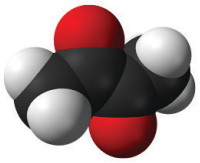
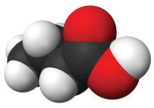
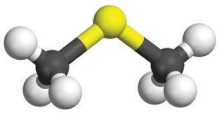
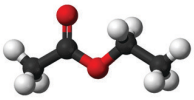
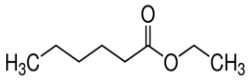
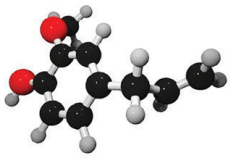
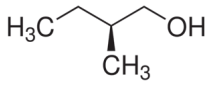
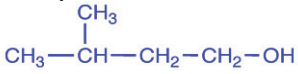
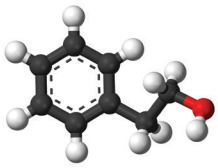
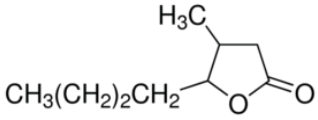
The American Craft Spirits Association - ACSA - 2015 Annual Conference in Austin Texas Feb 15-16. Flavors found in Distilled Spirits: Origins, Descriptors, Control.

GARY SPEDDING, Ph.D. [BREWING AND DISTILLING ANALYTICAL SERVICES, LLC] with
JOHNNY JEFFREY [ARTISAN DISTILLER]

Flavor Note/Specifics/ Examples	Descriptors/Info/Thresholds	Comments and Notes.
Acetaldehyde CH_3CHO (Ethanal) 	Green apples, bruised apples, grassy, latex paint. Fresh leafy, wet/cut grass, flower stems. Ethereal. Melon, pumpkin. Shown to rise from 14.4 ppm. initial to 21.1 ppm at 3 year and 39.6 ppm. at 6 yrs aging. (Data expressed at 40% abv) In a range of spirits from 8-240 ppm. Whiskies (incl, Bourbon), 16-100; Brandy 52-240 and Rum 8-60 ppm.	From stressed fermentation, oxidation aging reactions. Bacterial contaminations (incl Acetobacter). Oxidative formation of acetaldehyde and acetic from EtOH during maturation but most aldehydes in alc bevs are formed during fermentation. Maturation: Ethanol may be oxidized to acetaldehyde. Acetaldehyde may arise from the reduction of acetic acid.
2,3-Butanedione DIACETYL $CH_3COCOCH_3$ 	Butter, butterscotch, movie popcorn, sweetness, oiliness. Said to be at 0.02 ppm (20 ppb) odor threshold in imitation whisky [1 ppb. is like 1 mL in an Olympic sized pool or 4 drops in 50,000 gallons.] Whisky nosing odor recognition threshold (T) 0.04 ppm and taste at 0.2 mg/L Scotch whiskies 0.09-0.32 ppm. Brandy 0.07-0.31; Rum 0.03-4.4 ppm. (4400 ppb! - Buttery rums) and 0.01-0.10 ppm. in vodka.	From fermentation and bacterial spoilage. *Pediococcus* and *lactobacillus* can be involved. Diacetyl is produced by citrate-metabolisng LAB and in yeast fermentation. The mash and the fermentation conditions are similar for grain and malt whisky. Lactic acid bact –less imp to flavor in grain whisky and are suppressed > max increase in EtOH. 2,3-butanedione formed outside the yeast cell, via spontaneous decomposition of alpha-acetolactate (ALA). It can be readsorbed and metabolised to acetoin and then to 2,3-butanediol. Formation of alpha-acetolactate during fermtn. leads to diacetyl defects in final spirit.
MORE ON DIACETYL: Fermentation O_2 influences spirit diacetyl content. The amount of diacetyl depends upon FAN (nitrogen) level, pH and temperature. Limit amount of precursor (alpha acetolactate) by lower temp. ferm, good yeast growth and adequate areation. Alpha-acetolactate can be converted to diacetyl during the distillation. Reduce ALA by inc. the ferm. temperature. Late reduction of pH helps spontaneous decarboxylation of ALA – proceeds rapidly at pH 3.5. Conversion of ALA to diacetyl minimized by use of inert gases to protect wash from oxygen. Treatment with charcoal for white spirits such as vodka can remove undesirable compounds such as diacetyl by as much as 90%.		
Butyric acid $CH_3CH_2CH_2COOH$ (Butanoic acid) 	Rancid, sharp cheese, baby vomit/sickly-sour, pungent/putrid, sour spent grains. Aroma threshold is low - in beer its given as about 3 ppm. and possibly similar for whisky. High levels in rum and brandy. (10-14 ppm.)	From bacterial action (Clostridia) produced along with ethyl butyrate at low mash temp or if wash is allowed to stand in cast iron vessels. Notably positive in some rum fermtns. (Esp important in Heavy Rum) Butyric acid bacteria, *Clostridium butyricium*, *Cl. pasteurianum* and *Cl. saccharobutyricium*. Carbohydrates (CHO) are metabolised to Acetic (CH_3COOH) and Butyric Acids + CO_2 and H_2.
Dimethyl sulfide (DMS) CH_3SCH_3  	Cooked corn/sweetcorn/creamed corn, veggie-like, parsnip, tomato juice, quince, truffle, asparagus, oysters and the ocean (spray). [DMS above 100 ppb – cooked sweet corn, spicy malty or blackurrant notes. At lower concs. flavor impact not signif.] Threshold 35 ppb. Shown to decrease in barrel from 178 ppm – initial (values set as at 40% abv) to 29 ppm. at 3 years and traces at 6 years maturation - for Scotch whisky.	DMS is lost through evaporation in cask - so warehouse/storage conditions at play. Barley amino acids (cysteine and methionine) give rise to sulfur compounds. Malt yields DMS from S-methyl methionine (SMM) and this precursor depends on the temp and moisture of malt at the kiln. So DMS is formed in mashing from malt DMS precursor and can be oxidized to DMSO and $DMSO_2$. So issue with barley malt spirits. During fermentation DMSO is reduced to DMS. Anaerobic bacteria (Entero) in certain mashes can also produce DMS from DMSO. Oxidation of DMS to DMSO in maturation reduces it to low levels 50% DMS oxidized to DMSO and $DMSO_2$ after 96 hrs in cask – charcoal effects. Tannins and copper in cask can be imp. in degradn./removal of sulfurs. Adsorption by char. Oxidn. of DMS and other S compounds; reduced in concn. by adsorption/oxidation. Postulated that in aq. media the oxidation of gallic acid produces H_2O_2 – reactive – effectively oxidize sulfides.

Flavor Note/Specifics/ Examples	Descriptors/Info/Thresholds	Comments and Notes.
Ethyl acetate $CH_3COOCH_2CH_3$  **BPt: 77.1 °C Density:0.897g/cc Most common ester.**	**Acetone, (nail varnish remover), estery, paint thinner, solvent-like, with fruity nuances.** **Total esters (of which eth. acetate is the most common) quite high in Am whiskies (970 ppm.), Irish whiskies (808 ppm.), French Brandy (630-980 ppm.), Heavy rum (1584-2700 ppm.) and Jamaican rums (1732) ppm.** **In whiskey age at maturation (0): 59.2 ppm. Eth. acetate, 3 years 164.4 and at 6 years 523 ppm. Threshold (flavor): 20-30 ppm.**	**Ethyl esters rise due to esterification of free acids by ethanol. Formed late in fermentation.** **To control: Maintain same propagation conditions in fermentation each time. See lecture/presentation notes.** **Ethyl acetate can arise from wood-derived acetic acid or from oxidn of EtOH.** **Note for distillation the boiling point is very similar to that for ethanol (78.37 °C) so difficult to remove from heads (foreshots).**
Ethyl hexanoate $CH_3CH_2OCO(CH_2)_4CH_2$ **[Ethyl caproate]** 	**Estery, apple (red or fresh/ripe) with a hint of aniseed.** **Flavor threshold (in whiskey research) 0.17-0.21 ppm.** **There are many fruity esters but this is chosen as it is a good example of a fruity (not solventy) note.**	**Ethyl hexanoate is a volatile ethyl ester found in alcoholic beverages Formed from caproic (hexanoic acid) a medium chain fatty acid which itself is fatty, sweaty, cheesy in character. From yeast during fermentation and also from Clostridium spps (bacteria - see also Butyric acid).** **Ethyl hexanoate is responsible for flowery/fruity aromas, e.g. pineapple, blackberry, apple-peel and strawberry aromas. The concentrations of ethyl esters decrease over time as an alcoholic beverage ages due to spontaneous hydrolysis.**
Eugenol $C_{10}H_{12}O_2$ **[4-allyl-2-methoxyphenol]** 	**Spicy-clove, cinnamon, ginger, aromatic and nutmeg (not to be conmfused with similar notes from guaiacols – more smoky spicy),** **Threshold 50 ppb. in 20% EtOH and recognition T: 4.9 ppm. in 23% grain spirit.** **Notable in Bourbon and Canadian whiskey with typical recognition T of 5 ppb! Grain whisky at odor threshold at four years.**	**From oak. Like most phenolics extracted from wood by alcoholysis of lignin. Increased by thermal degradation of oak. Clove like (more prevalent in untreated oak?)** **Arises from new staves after charring and ethanolic extraction or from cereal cell walls. Eugenol derives from lipid oxidation.**
Fusel Oils		
2-Methyl-1-Butanol* **active amyl alcohol**  **3-Methyl-1-Butanol*** **isoamyl alcohol** 	**Alcoholic, spicy, vinous, pungent, warming.** ***Both the major oils are given flavor threshold values (in beer) of 50-70 ppm.** **Main are – active and iso amyl alcohol with these being at 410-475 ppm. in Scotch, 150-230 in Canadian, 1685 in Bourbon and 422-990 ppm in French Brandy.**	**Mix of aliphatic alcohols (volatile oily liquids) including 1-propanol, 2-methyl propanol (75 mg/L threshold) and 2-methyl butanol and 3 methyl butanol. A typical fusel oil contains 60–70 percent of amyl alcohol.** **Formed in fermentation by decarboxylation and deamination of amino acids: Leucine to isoamylalcohol and isoleucine to active amyl alcohol.** **Any condition that stimulates yeast growth will stilulate fusel oil; production. Yeast strain dependent, temperature dependent. Aeration, lipid content and FAN levels of mash/wort important along with degree of agitation and pH.**
Phenethyl alcohol 		**Phenylethanol: Atomatic-aliphatic fusel oil (From phe ala) Positive contributor. 5-32 ppm in whiskeys and 131 ppm in Straight Bourbon**
WHISKY LACTONE 	**At 12pp. in spirits? Oaky, sl. Coconut aroma. Different oak – diff amounts. Am oak higher than French.** **Notable in matured spirits in new chsarred casks and higher conce in higher strength alcohol spirit maturations. Lactones imp aroma compounds and notable amount in Jamaican Rum.**	**WHISKY LACTONE: (Oak lactone, □-methyl- octalactone, Quercus lactone, 5-butyl-4-methyloxalan-2-one.** **Cis-isomer – coconut like aroma BPt. 124-126°C Oakwood aroma.** **OAK LACTONE: (more prevalent in untreated oak?) cis oak lactone at 20 x odor threshold .**

A full set of these notes in color provided upon request along with a more extensive listing of flavors and properties. www.alcbevtesting.com