WHEAT BEER FLAVOR

from thirteen different yeasts in head-to-head comparison

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Objectives

- Compare flavors of 13 wheat beers that differ only in the yeast strain used
- Generate information for the selection of yeast strains for brewing wheat beers

Wheat Beer Recipe

Malt Bill

Two row pale	70 lbs	50%
Malted Wheat	30 lbs.	21%
Unmalted Wheat	30 lbs.	21%
Crystal 60 L	3 lbs.	02%
Munich 10 L	8 lbs.	06%
TOTAL	141 lbs	100%

Hops:

Saaz 16.8 oz.

Mash Schedule

Temp. Degrees F	Rest Time in minutes	
122º	30	
144º	30	
152º	30	
155º	20	
170º	Rest/ vorlauf/ sparge…	2 bbls. Kettle full

Boil

Total boil time: 1hour

Addition/Boil Time	Hops	Weight
45 minute Hops	Saaz	11.1 oz
15 minute Hops	Saaz	5.7 oz

Original Gravity: 1.058

Jess Caudill – Wyeast Microbiologist & Brewer

Wort was divided into 13 fermenters and pitched at 6 X 10^6 per ml of the following strains. Fermentation temperature was 68º - 70º with an original gravity of 1.058.

Strain		Final Gravity
1010	American Wheat	1.011
3522	Belgian Ardennes	1.012
1762	Belgian Abbey II	1.011
1214	Belgian Ale	1.011
3787	Trappist High Gravity	1.010
3538	Leuven Pale Ale	1.011
3864	Canadian Belgian	1.013

Strain		Final Gravity
3463	Forbidden Fruit	1.011
3944	Belgian Wit bier	1.011
3942	Belgian Wheat	1.011
3333	German Wheat	1.012
3638	Bavarian Wheat	1.011
3068	Weihenstephan **Wheat**	1.011

Most beers were at terminal gravity by day 5.

Primary, Secondary and Tertiary Flavors

$$\text{FU} = \frac{\text{concentration in beer in mg/l}}{\text{threshold in mg/l}}$$

2 FU =	**Primary Flavor**
0.5–2.0 FU =	**Secondary Flavor**
< 0.5 FU =	**Tertiary Flavor**

The unique flavor of Wheat Beers comes from alcohols, esters, phenols as well as other compounds.

Phenol Production

from the literature

- Increase in phenols follows the main and secondary fermentations
- Phenol-carbon acids are decarboxylated into phenols by yeast
- Weizen beer yeast can decarboxylate ferulic acid into 4-vinyl guaiacol
- Ferulic acid production occurs most successfully in mashing at 44 C and pH 5.7

Phenolics in Wheat Beers

from the literature

Phenolic substances:	Avg value(ppb) or Aroma (threshold)	Characteristic Flavor
4-vinyl guiacol	1500	clove-like(~1000ppb)
4-vinyl phenol	970	phenolic
4-hydroxy benzaldehyde	125	phenolically bitter
phenol	40	phenolic, cresol-like
4-vinyl syringol	310	smoky aroma and flavor
guaiacol	120	phenolic, medicinal, smoky
vanillin/acetovanillon	153	vanilla
eugenol	70	phenolic
isoeugenol	38	clove-like, nutmeg-like
styrene		resiny, plastic-like, harsh

Higher Alcohol Production

from the literature

- Mainly produced during Primary fermentation
- Fusel alcohols are produced through the metabolism of amino acids
- Fusel alcohols are those other than ethanol
- Common examples are isoamyl alcohol and phenyl ethyl alcohol
- Increase complexity and fullness of beer at low level; harsh at high levels

Higher Alcohols in Wheat Beers

from the literature

Higher alcohols: :	Avg value(ppm)	Characteristic Flavor or Aroma	Threshold
1-propanol	18.80	fusel, solvent-like	?
2-methyl-1-propanol	36.50	alcohol, solvent-like	10-200 ppm
2-methyl-1-butanol (amyl alcohol)	20.10	alcohol, solvent-like	10-65
3-methyl-1-butanol (isoamyl alcohol)	58.00	alcohol, banana	30-70
phenyl ethyl alcohol	33.0	rose or rose oil	28-135

Ester production

from the literature

- Acetate ester excretion is rapid and complete after yeast growth complete
- Fatty acid ethyl esters take longer to produce
- Formed as a by-product of acetyl CoA and alcohols
- Most ale yeast produce lower levels of esters compared to lager yeasts under similar fermentation conditions
- Common examples are ethyl acetate, isoamyl acetate and ethyl hexanoate

Esters in Wheat Beer

from the literature

Ester:	Avg value(ppm)	Characteristic Flavor or Aroma	Threshold value
Ethyl acetate	32.0	solvent-like (acetone),	25-30
Isoamyl acetate	3.00-4.00	very fruity, banana	1.0-1.6
Hexanoic acid ethyl ester (ethyl caproate)	0.12	fruity, apple	
Octanoic acid ethyl ester (ethyl caprylate)	0.25	fruity, winy	
Decanoic acid ethyl ester (ethyl caprate)	0.05	fruity, winy	
Phenyl ethyl acetate	0.98	rose	

Other Esters

Ester:	Characteristic Flavor or Aroma	Threshold value (ppm)
Ethyl heptanoate	fruity, pineapple	
Ethyl butyrate	grape, apple	0.4
Isobutyl acetate	fruity, banana	0.4-1.6

Other Flavor Components

from the literature

Flavor component:	Avg value(ppm)	Characteristic Flavor or Aroma	Threshold value
Beta-damascenone		**dried fruit, rose**	
Maltol		**sweet**	
DMS	**42.0 ppb**	**cooked vegetable**	**50.0-80.0ppb**
Diacetyl	**0.04**	**butterscotch**	**0.10-0.15**
Acetaldehyde	**0.40**	**acidic, pungent, sharp**	**10**

Flavor Panel Results

experimental

Wheat beers are characterized specifically by:

‘spicy’

‘clove’

‘phenolic’

And generally as with other beers by different levels of:

‘fruity’

‘banana’

‘floral’

‘sulfury’

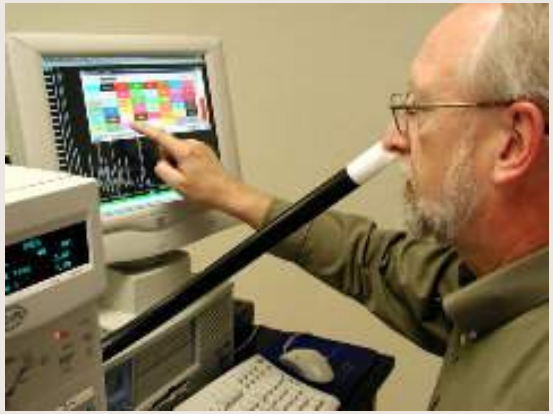
& others

GC-Olfactometry

instrumental / human interactive flavor analysis

flavor components

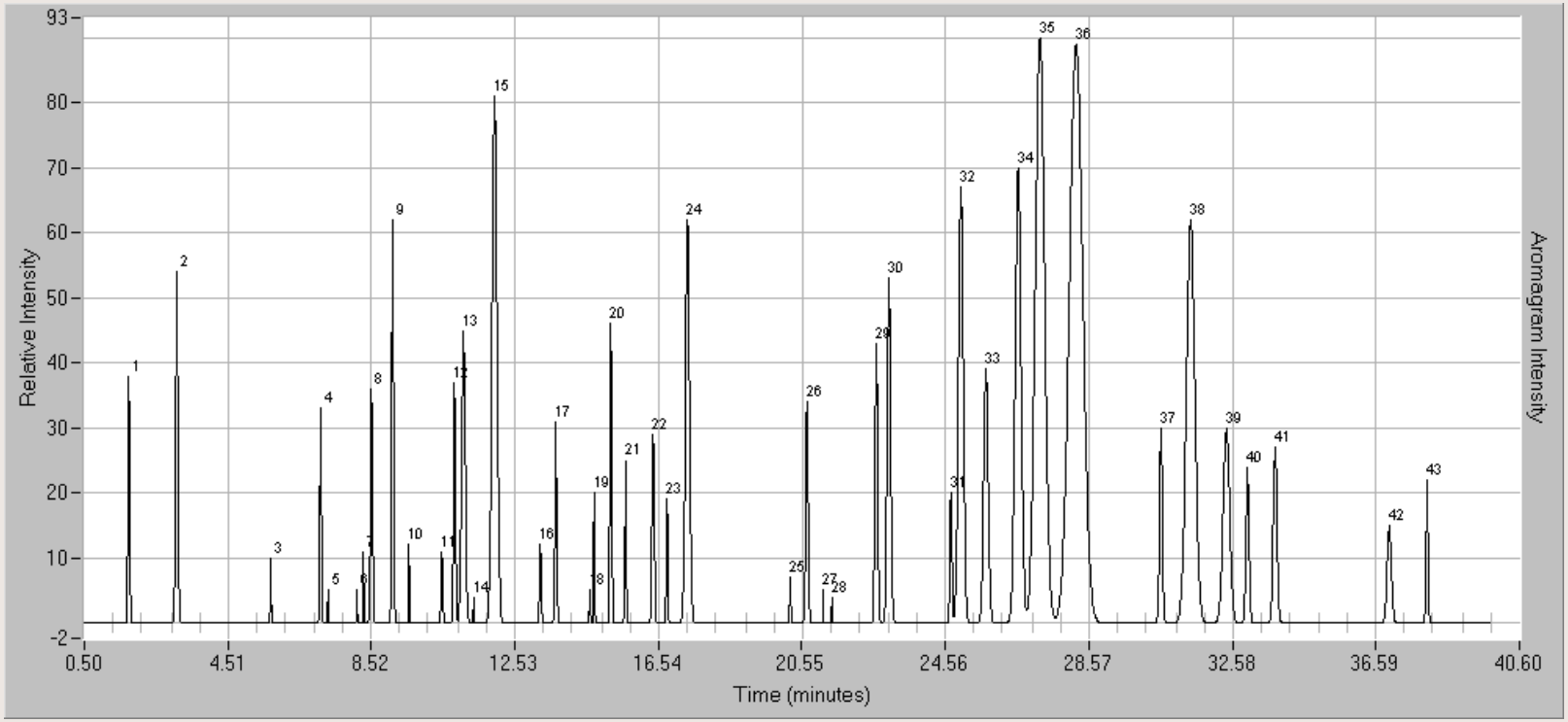
- separated
- characters defined
- identified
- quantified
- correlated to panel



GC-O Aromagram

separation of individual flavors

Major headspace flavors in Trappist high gravity wheat beer yeast



Aromagram Flavor Notes

individual flavors characterized

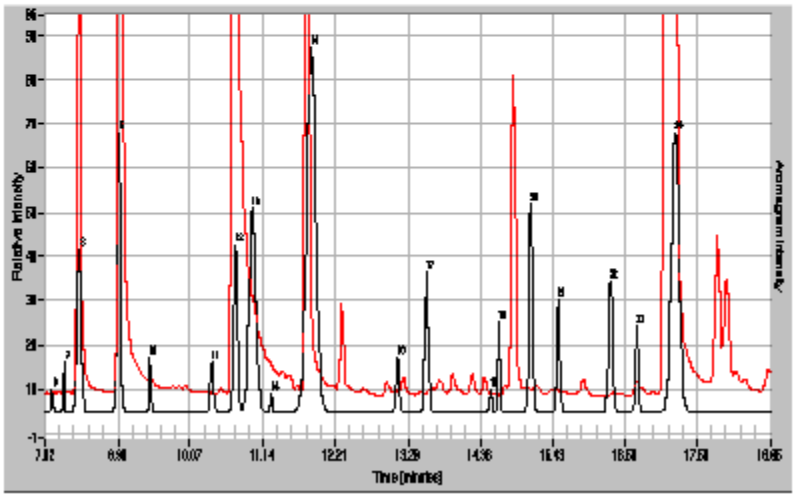
Aquisition Date : 04/21/2003				
Aquisition Time : 14:53:52				
Wyeast 2, 3787				
SPME: 5 hour collection				
Event#	Descriptor	Intensity	Start Time	Event Area
1	Acetaldehyde	38	1.69	455
2	Ethanol	54	3	916
3	Ester	10	5.68	69
4	Grape	33	7.05	395
5	Ester	5	7.28	29
6	Ester	5	8.09	34
7	Ester	11	8.28	54
8	Fusel Oil	36	8.45	575
9	Banana	62	9.04	866
10	Ester	12	9.54	83
11	Unknown	11	10.43	142
12	Resiny	37	10.77	554
13	Ester	45	10.95	1257
14	Nutty	4	11.35	19
15	Ester	81	11.78	2992
16	Sewer	12	13.19	143
17	Herbaceous	31	13.61	433
18	Herbaceous	5	14.59	39
19	Roasted	20	14.71	159
20	Hops, citrus	46	15.15	597
21	Musty	25	15.57	274
22	Herbaceous	29	16.31	492
23	Herbaceous	19	16.73	208
24	Ester	62	17.2	1918
25	Ester	7	20.18	69
26	Cooked Cereal	34	20.61	610
27	Unknown	5	21.12	14
28	Unknown	4	21.35	23
29	Hops, resiny	43	22.53	858
30	Hops	53	22.85	1375
31	Ester	20	24.64	319
32	Rose	67	24.81	2474
33	Cooked Grain	39	25.53	1323
34	Rose	70	26.37	3144
35	Damascenone	90	26.85	6469
36	Maltol	89	27.7	9062
37	Spicy	30	30.48	658
38	Cooked Cereal	62	31.09	4023
39	Spicy	30	32.17	1497
40	Spicy	24	32.9	551
41	Sweet	27	33.63	781
42	Cooked Grain	15	36.8	494
43	Cooked Cereal	22	37.95	329

Simultaneous GC-O / GC-MS

flavors chemically identified

Microanalytics AromaTrax Report 04/22/2003 @ 08:04:08

Sample Description:	Wyeast 2, 3787, new brew
Remarks:	SPME: 5 hour collection
Analysis Date:	04/21/2003
Analysis Time:	14:53:52
Method File:	FASTBEER.MTH
Raw Data File:	No File Loaded
Results File:	WY2-5X.RS2
Number of Notes:	43



Correlation of aromagram flavors with overlaid mass spec chromatogram

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Even the most trace level flavor compound can be characterized, identified, quantified and related to flavor panel results.

Spicy, Clove & Phenolic

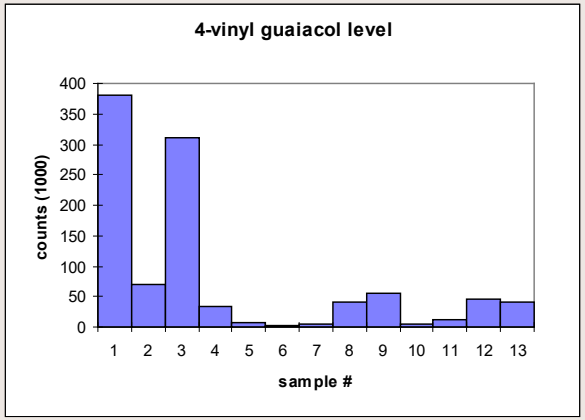
flavors quantified, correlated with flavor panel

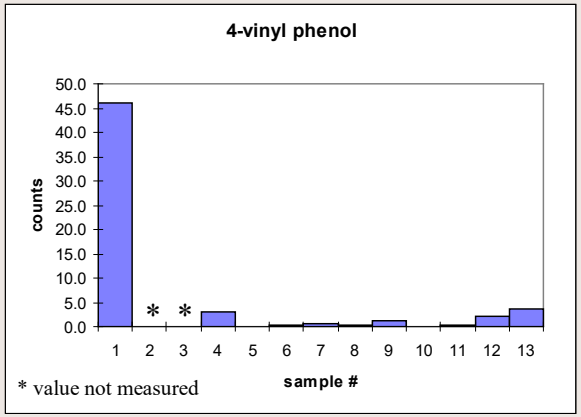
1) The specific spicy flavor of clove is due to 4-vinyl guaiacol.

2) 4-vinyl guaiacol concentration is shown by the data to be dependent on the yeast strain.

3) 4-vinyl phenol is the only other phenolic present but it contributes no significant flavor.

#	yeast type	4-vinyl guaiacol	GC-O value: 4-vinyl guaiacol	4-vinyl phenol	flavor panel: selected aromas from overall beer evaluation
1	Belgian Ale Yeast	380	4780	46.0	clove, spicey
2	Trappist High Gravity	70	2955	no value	spicy
3	Belgian Ardennes Yeast	310	5216	no value	clove, spicey
4	German Wheat Yeast	34	419	2.9	clove, spicey
5	Weihenstephen Weizen Yeast	7.5	973	<	clove
6	American Wheat	2.7	0	0.2	none
7	Belgian Abbey Yeast II	6.0	0	0.6	none
8	Forbidden Fruit Yeast	42	1016	0.4	clove, spicey
9	Belgian Wheat Yeast	56	838	1.2	spicy
10	Belgian Whitbier Yeast	5.5	0	<	spicy
11	Bavarian Wheat Yeast	12.5	571	0.3	spicy
12	Canadian/Belgian Style Yeast	45	830	2.0	clove, spicey
13	Leuven Pale Ale Yeast	40	1030	3.5	clove, spicey





* value not measured

Resiny

a unique wheat beer characteristic

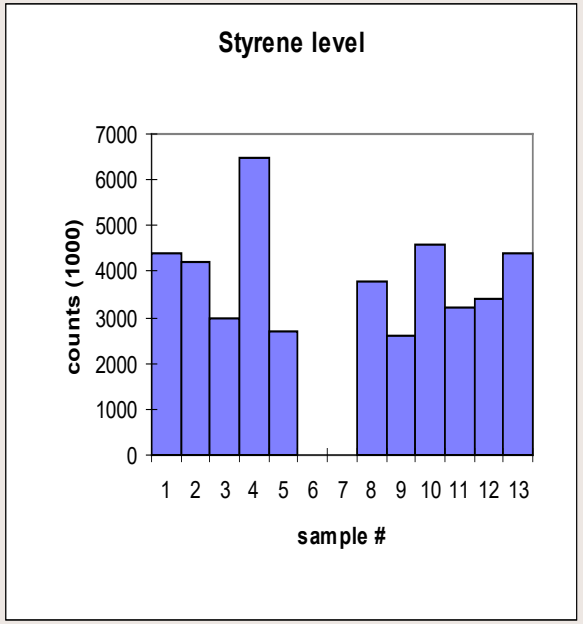
1) Styrene concentration is shown by the data to be dependent on the yeast strain.

2) Styrene has a chemical resiny, harsh plastic flavor and may be called phenolic by some.

3) Styrene flavor is important for wheat beer flavor. Some people can apparently pick it out of the total flavor profile. Our data indicate that yeast strains 6 and 7 do not give a full wheat beer flavor profile.

4) We have previously shown that commercial German wheat beers have significant levels of styrene and the present data indicate that all but two of the yeast strains produce it.

#	yeast type	styrene (thousands of counts of ion 104)	GC-O value	flavor panel (selected odors)
1	Belgian Ale Yeast	4400	1631	
2	Trappist High Gravity	4200	323	
3	Belgian Ardennes Yeast	3000	1105	burnt, oxidized
4	German Wheat Yeast	6500	1722	resiny, oxidized
5	Weihenstephen Weizen Yeast	2700	1269	burnt, smokey
6	American Wheat	22	0	
7	Belgian Abbey Yeast II	18	0	
8	Forbidden Fruit Yeast	3800	613	olive-like, smokey, phenolic
9	Belgian Wheat Yeast	2600	337	resiny, olive-like, smokey
10	Belgian Whitbier Yeast	4600	3054	phenolic
11	Bavarian Wheat Yeast	3200	1069	resiny
12	Canadian/Belgian Style Yeast	3400	1940	oxidized
13	Leuven Pale Ale Yeast	4400	1557	plastic, styrene, oxidized



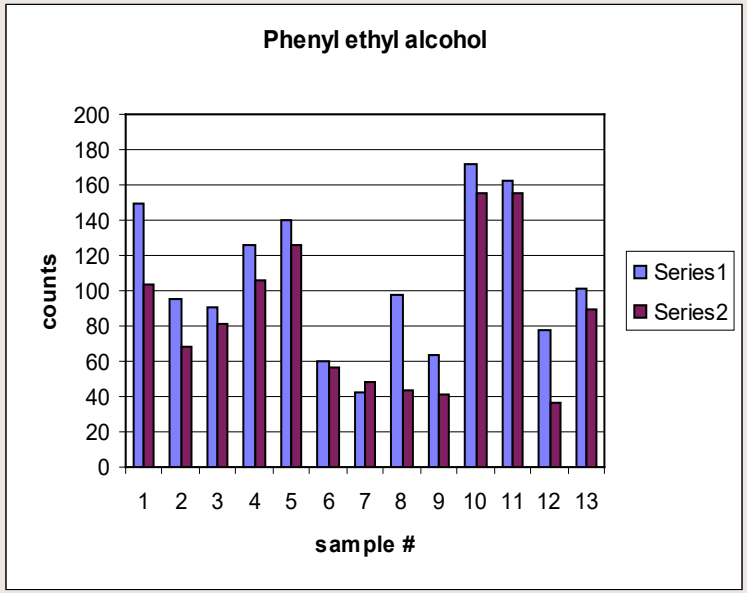
Phenyl ethyl alcohol

rose

1) Phenyl ethyl alcohol is a yeast metabolite and is necessary for the recognized flavor of beer.

2) The concentration of phenyl ethyl alcohol depends on the strain of yeast and it is often one of the most concentrated flavors in beer.

3) The data here shows the results for two different variations of the method of analysis.



series 1 data from 1 hour standard method	
series 2 data from 5 hour SPME collection in bottle	

#	yeast type	phenylethyl alcohol (millions of counts total ions)	phenylethyl alcohol (ten thousands of counts of ion 122)	GC-O value
1	Belgian Ale Yeast	149	103	3647
2	Trappist High Gravity	95	68	5894
3	Belgian Ardennes Yeast	91	81	3888
4	German Wheat Yeast	126	106	4831
5	Weihenstephen Weizen Yeast	140	126	4542
6	American Wheat	60	56	2783
7	Belgian Abbey Yeast II	42	48	4722
8	Forbidden Fruit Yeast	97	44	4836
9	Belgian Wheat Yeast	64	41	2036
10	Belgian Whitbier Yeast	172	155	4516
11	Bavarian Wheat Yeast	162	155	4304
12	Canadian/Belgian Style Yeast	77	37	3277
13	Leuven Pale Ale Yeast	101	89	4451
		series 1	series 2	

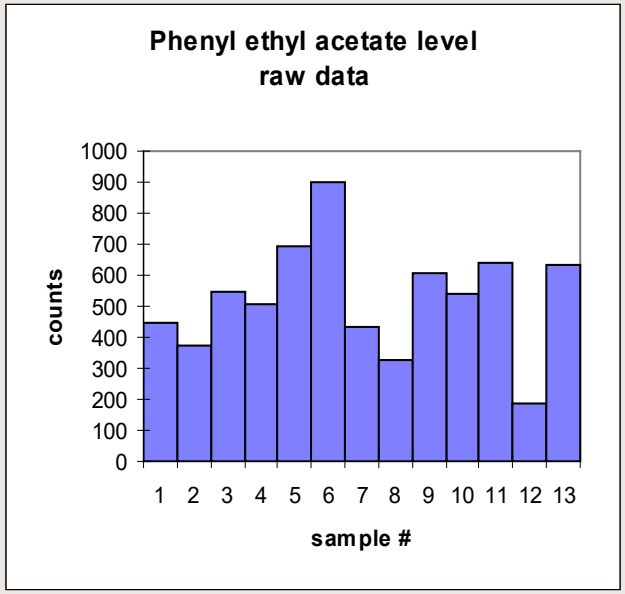
Phenyl ethyl acetate

the other rose

1) Phenyl ethyl acetate is a yeast metabolite with a similar rose aroma like phenyl ethyl alcohol and contributes to the overall floral.

2) Flavor panelists do not generally pick up a distinctive rose aroma in beer samples and in the case of the wheat beers, only rarely do they describe the wheat beers as having a floral note.

#	yeast type	phenyl ethyl acetate	hp internal standard (ion 75)	phenyl ethyl acetate normalized	GC-O intensity value
1	Belgian Ale Yeast	450	4680	962	61
2	Trappist High Gravity	376	6830	551	41
3	Belgian Ardennes Yeast	544	7180	758	65
4	German Wheat Yeast	504	5480	920	54
5	Weihenstephen Weizen Yeast	694	7700	901	85
6	American Wheat	900	5700	1579	52
7	Belgian Abbey Yeast II	431	5740	751	63
8	Forbidden Fruit Yeast	325	3860	842	47
9	Belgian Wheat Yeast	604	5040	1198	58
10	Belgian Whitbier Yeast	540	5724	943	64
11	Bavarian Wheat Yeast	639	6540	977	58
12	Canadian/Belgian Style Yeast	188	4960	379	58
13	Leuven Pale Ale Yeast	631	4980	1267	68

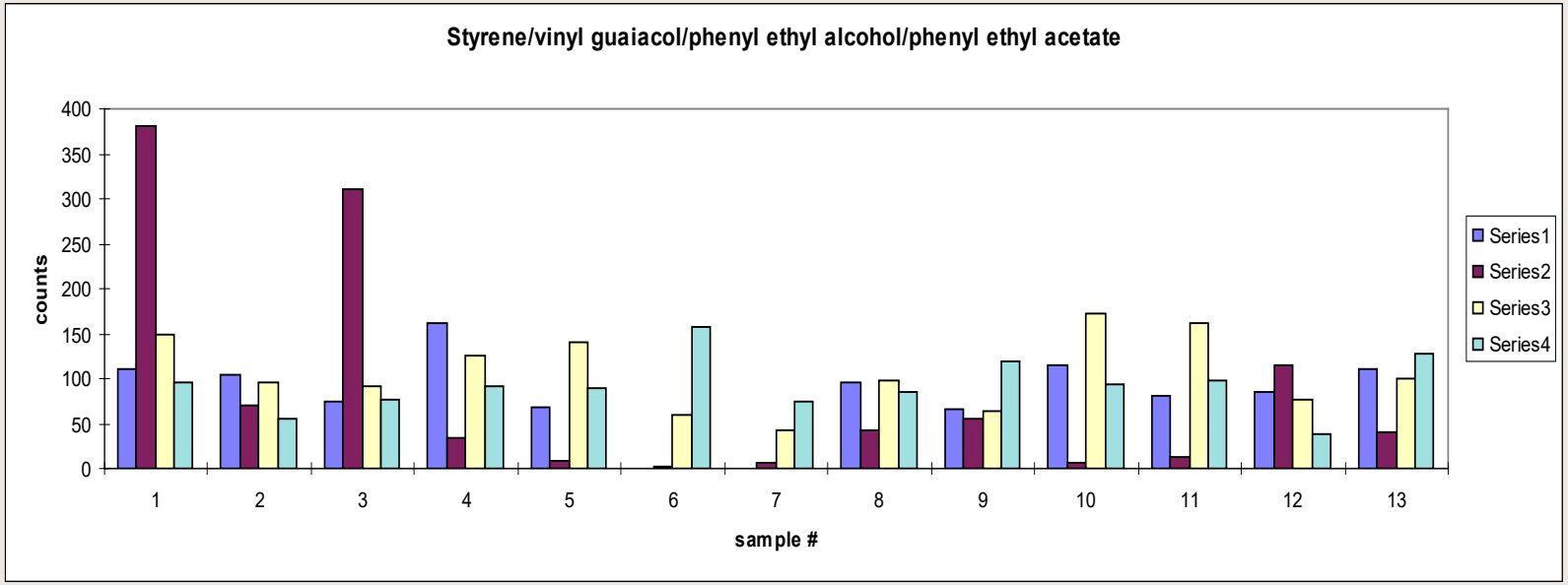


Aromatic-based Flavors:

styrene/vinyl-guaiacol/phenyl ethyl alcohol/phenyl ethyl acetate

1) The same two beers that have no styrene, samples 6 and 7, also have very low levels of 4-vinyl-guaiacol. This suggests a metabolic link between styrene and 4-vinyl guaiacol.

2) It is also seen that there is generally a correlation between styrene and phenyl ethyl alcohol concentrations.



Note: The counts scales are different for each compound

Series 1: styrene

Series 2: 4-vinyl guaiacol

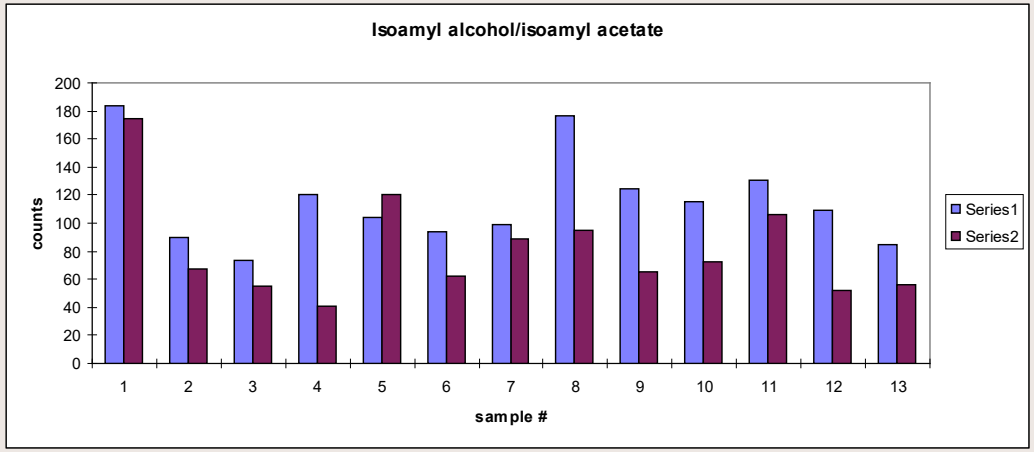
Series 3: phenyl ethyl alcohol

Series 4: phenyl ethyl acetate

Fruity

banana & fusel oil

#	yeast type	isoamyl acetate normalized	GC-O value	Isoamyl alcohol normalized	GC-O value	flavor panel
1	Belgian Ale Yeast	87.4	1537	184	712	strong banana
2	Trappist High Gravity	33.5	1413	90	682	
3	Belgian Ardennes Yeast	27.3	1102	73	1054	banana
4	German Wheat Yeast	20.4	846	120	1515	banana
5	Weihenstephen Weizen Yeast	60.3	1946	104	1293	strong banana
6	American Wheat	31.1	1584	94	1896	
7	Belgian Abbey Yeast II	44.3	2197	99	1856	
8	Forbidden Fruit Yeast	47.2	694	177	1153	
9	Belgian Wheat Yeast	32.9	527	124	664	banana
10	Belgian Whitbier Yeast	36.2	1062	115	591	
11	Bavarian Wheat Yeast	52.9	1213	131	1563	strong banana
12	Canadian/Belgian Style Yeast	26.2	998	109	1198	
13	Leuven Pale Ale Yeast	27.9	835	85	449	banana



1) Isoamyl acetate is the yeast metabolite responsible for the banana flavor in beer.

2) Sample 1, 5 and 11 have the highest amounts of isoamyl acetate and these where found to have the strongest banana flavor by the panel.

3) The samples with lower levels of isoamyl acetate have their banana flavor blended with the other fruity notes so that no distinct banana is perceived.

4) Isoamyl alcohol is a yeast metabolite which is responsible for the fusel oil note in beer.

5) Isoamyl alcohol is the only other aliphatic alcohol in beer besides ethanol present at levels that make a flavor contribution.

series 1 is isoamyl alcohol
series 2 is isoamyl acetate * 2

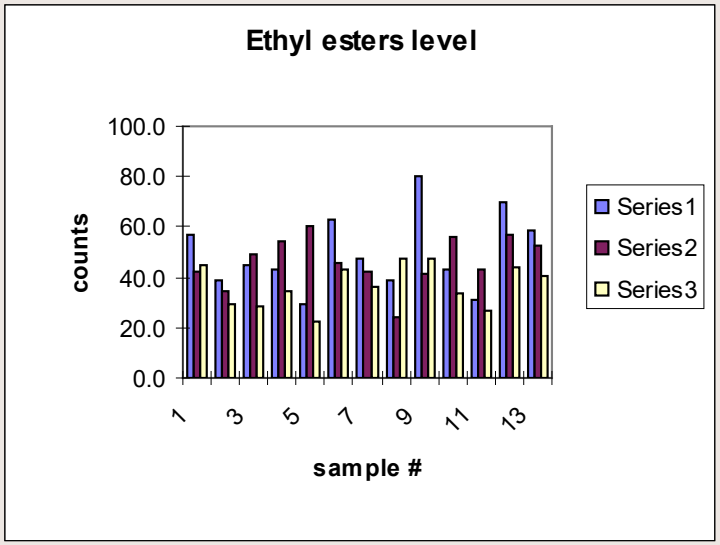
Fruity

ethyl esters vs. ethyl acetates

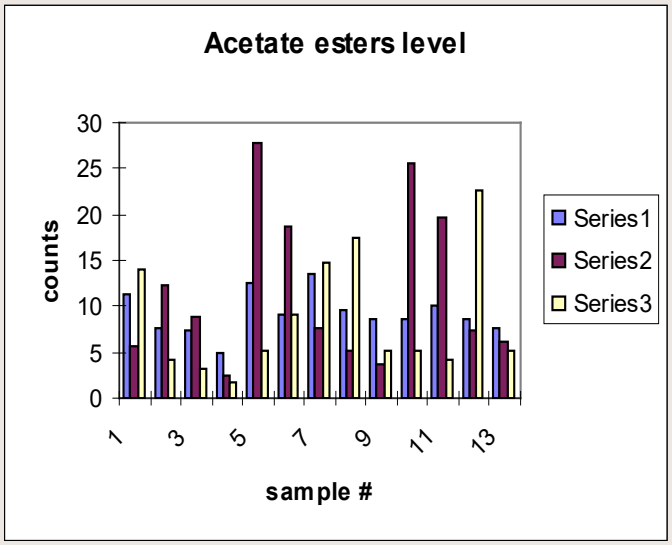
1) The fruitiness and some of the sweetness of the samples as characterized by the flavor panel is due to the numerous esters.

2) They are grape-like, apple-like, bubblegum-like and cereal-like and all have some degree of sweetness.

3) The overall fruity character from the esters depends on the proportions of all the esters in a particular sample.



series 1 is ethyl hexanoate normalized * 2000
series 2 is ethyl heptanoate normalized * 80000
series 3 is ethyl octanoate normalized * 100



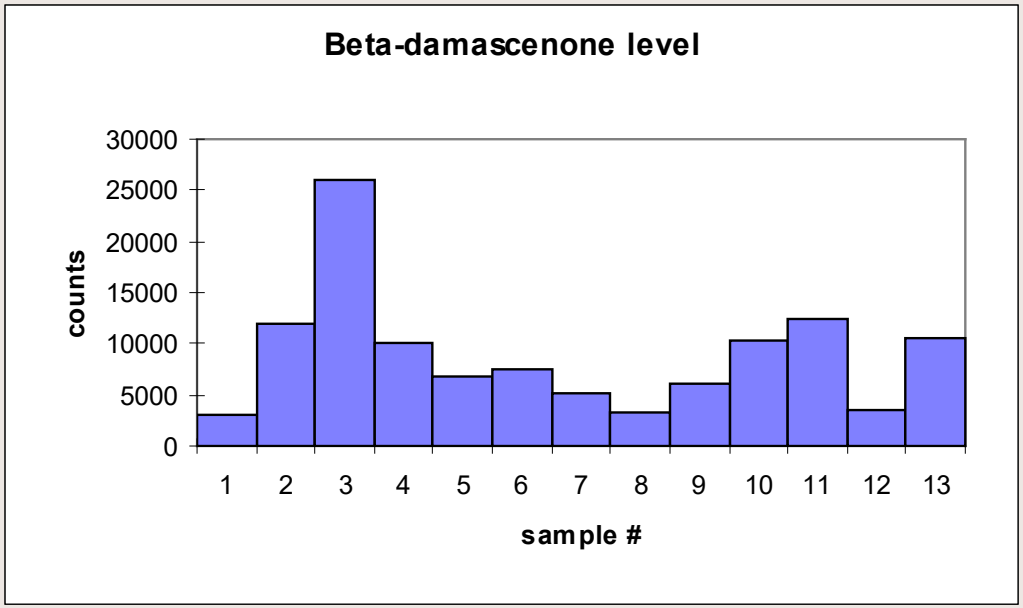
series 1 is hexyl acetate normalized * 5000
series 2 is heptyl acetate normalize * 10000
series 3 is octyl acetate normalized * 10000

Dried Fruit

beta-damascenone

1) Beta-damascenone is a yeast metabolite and is found at trace levels in beer. It has very intense and has a distinct flavor character. It is sweet with a dried fruit, burley tobacco and tea leaf flavor. Its flavor is both fruity and somewhat floral and very pleasing.

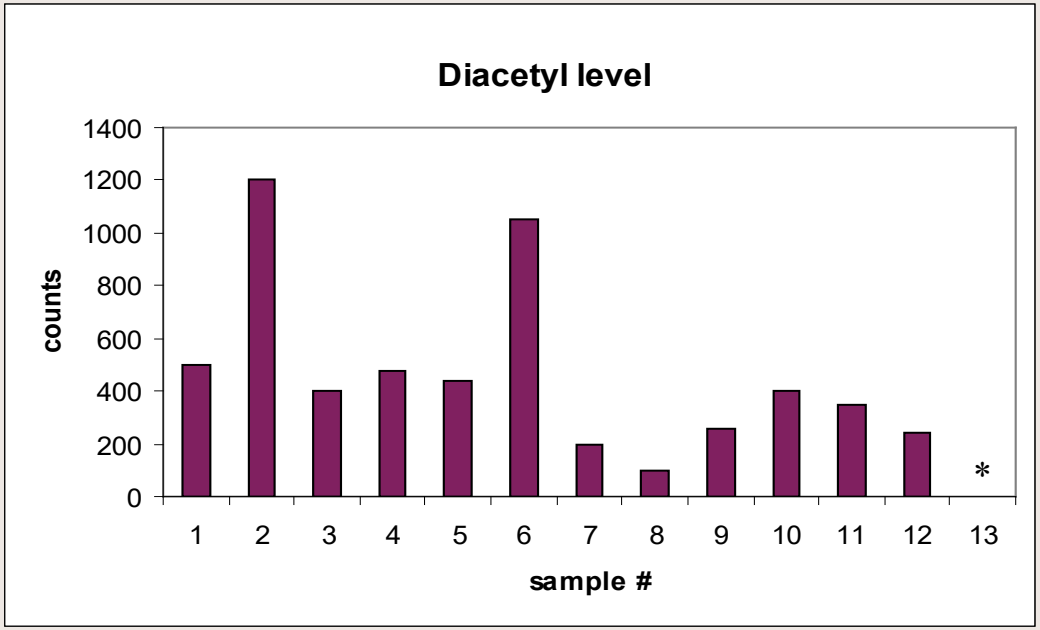
2) Because it is present at only a trace level, it is difficult to analyze with the present method with any precision. The data above are probably not precise enough to draw any flavor correlation conclusions.



Buttery
diacetyl

1) The values for diacetyl are extremely low for all the samples.

2) None of the samples has a level of diacetyl that is detected at the sniff port.



* value missing

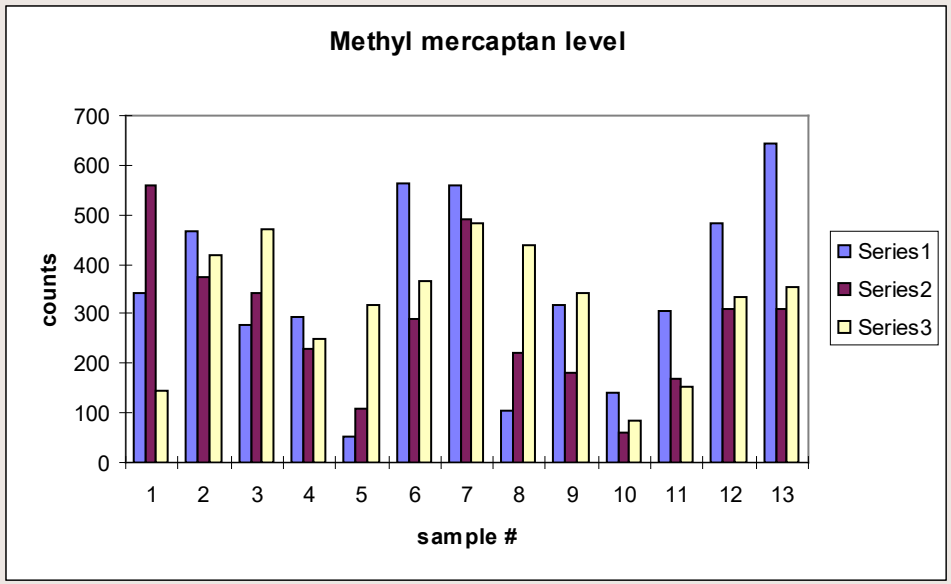
Sulfur-based Flavors

methyl mercaptan; fecal

1) Methyl mercaptan is very volatile and is only perceptible in the top note headspace of these wheat beers. It apparently is not tasted to any extent.

2) Some methyl mercaptan comes from the hops and grain, but some may come from yeast metabolism, possibly under specific conditions.

3) Methyl mercaptan is not 'skunky' but has a fecal character.



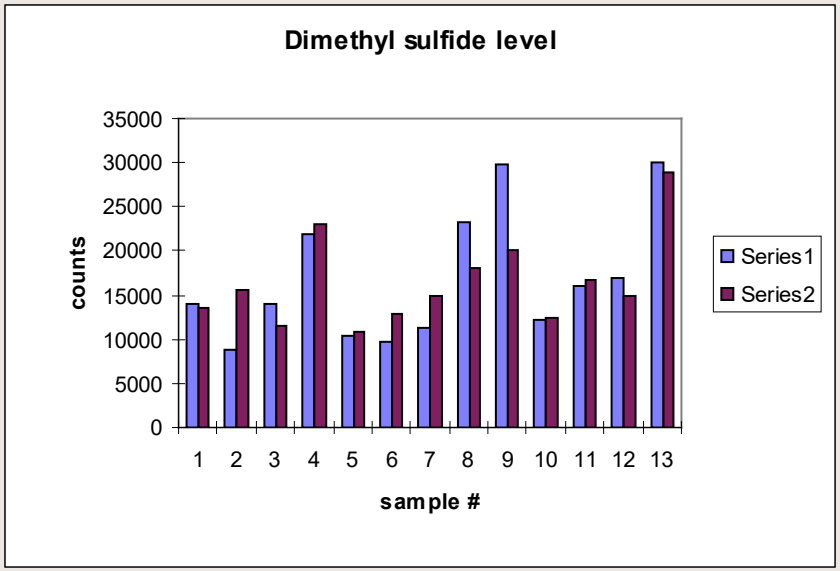
series 1 is standard method
series 2 is direct bottle sampling
series 3 is GC-O value

Sulfur-based Flavors

dimethyl sulfide; milky, creamed corn

1) Dimethyl sulfide has a milky or canned corn aroma. It is considered by some to give an off-flavor to beer and it is found in all beer to some degree.

2) It is at low levels in all these beers and can not be picked out of the total flavor by the flavor panel.



series 1 is standard method
series 2 is direct bottle sampling

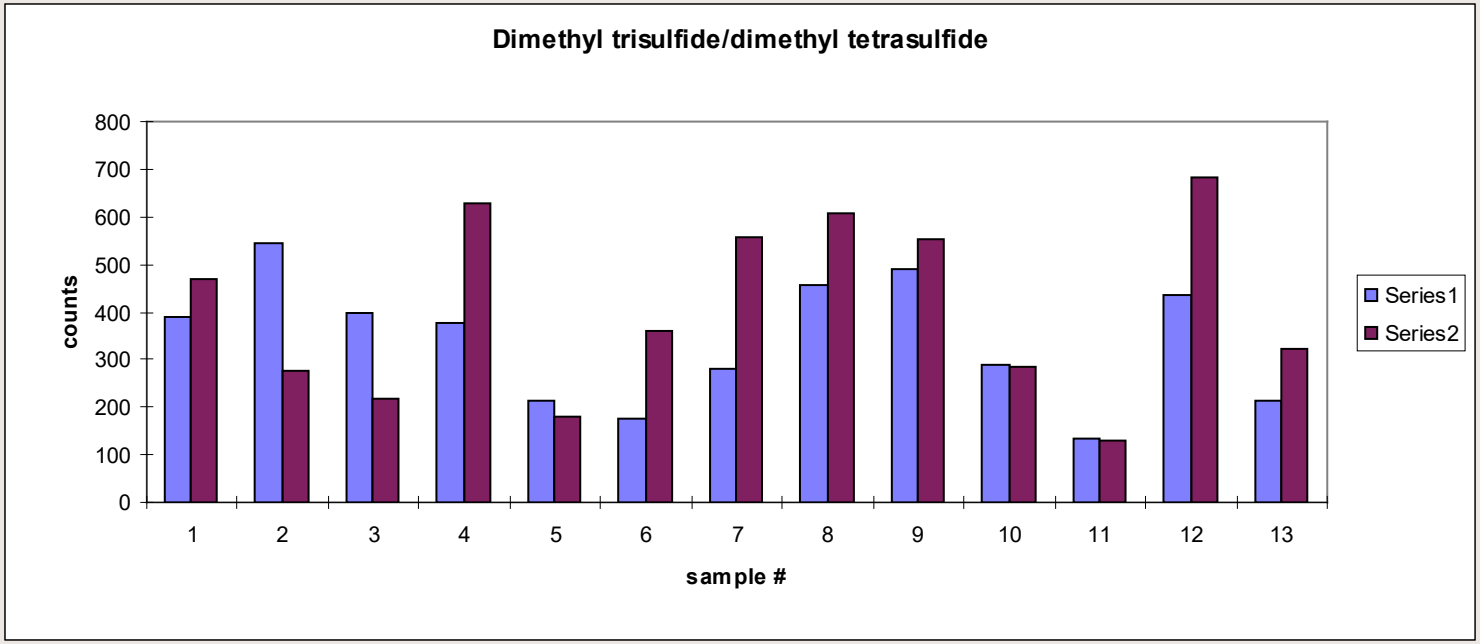
Sulfur-based Flavors

dimethyl trisulfide/dimethyl tetrasulfide; sewer

1) Dimethyl trisulfide is found in all beers at low levels. It has a distinct foul, sewer odor that can also give a vegetable, cabbage or broccoli impression.

2) Dimethyl tetrasulfide was also detected in all 13 samples but at very low levels in the headspace, much below DMTS.

3) A certain level of DMTS may be a positive trait for beer. DMTS is known to come from hops and grain, but from the following data, it appears that yeast may also contribute significantly.



Wheat Beer Tasting

Enough of the analytical details, its time to form your own flavor opinions…….