Correlation Between Sensory Analysis and Volatile Composition of Beer using Multivariate Analysis: Effect of the Beer Matrix on the Sensory Perception and Volatile Fraction Behavior

Ph.D. Luis F. Castro

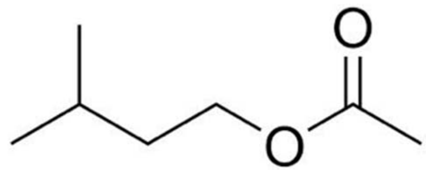
Ph.D. Carolyn F. Ross

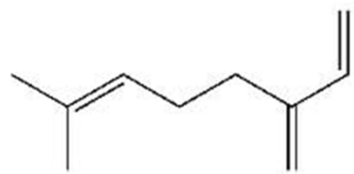
School of Food Science, Washington State University

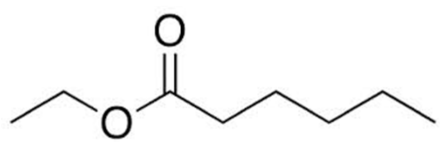
The Science of Beer

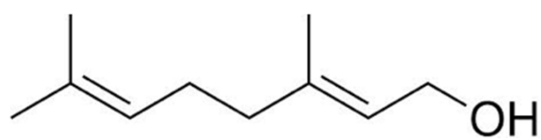

Fruity
Clean and Malty
Light and Sweet
Roasty
The Bitter Way
Complex and Heavy
The Light Side
Fruit Ale
•Raspberry Tart by New Glarus
•Banana Bread Beer by Wells & Young's Ltd
•Berry Weiss by Leinenkugel's
•Belgian Red by New Glarus
Light Fruit Ale
•Apricot Ale by Pyramid
•Summer Shandy by Leinie's
•Purple Haze by Abita
Saison
•Red Barn Ale by Lost Abbey
•Saison by New Belgium
Doppelbock
•Autumnal Fire by Capital
•Optimator by Spaten
•Double Bock by Samuel Adams
Bock
•Rockefeller Bock by Great Lakes
•Long Shot Bock by Sam Adams
•Many Local Breweries have a standard bock
Maibock
•Maibock by Capital
•Dead Guy Ale by Rogue Ales
Hefeweizen
•Dancing Man Wheat by New Glarus
•Hefe-Weisse by Franziskaner
•Crack'd Wheat by New Glarus
•Weisse by Schneider
American Wheat
•Gumballhead by Three Floyd's
•Oberon Ale by Bell's
Witbier
•Wit by Hoegaarden
•Sunset Wheat by Leinie's
Red Ale
•Smithwick's By Guinness
•Killian's Irish Red by Coors
Brown Porter
•Edmund Fitzgerald by Great Lakes
•Contorter by Ale Asylum
Stouts
•Draught by Guinness
•Cream Stout by Samuel Adams
•Coffee Stout by Central Waters
Pale Ale
•Bass Ale
•Moondog Ale by Great Lakes
India Pale Ale
•60 minute IPA by Dogfish Head
•Two Hearted Ale by Bell's
•IPA by Goose Island
Imperial IPA
•90 minute IPA by Dogfish Head
•Hop Slam by Bell's
•Imperial IPA by Goose Island
•Dreadnaught by Three Floyd's
Strong Golden Ale
•Duvel
•Delirium Tremens
Belgian Tripel
•Tripel by New Belgium
•Tripel by St. Bernardus
•La Fin Du Monde by Unibroue
Belgian Dubbel
•Pater 6 by St. Bernardus
•Abbey by New Belgium
Std. American Lager
•Budweiser
•Coors
•Molson
•MGD
Light Lager
•Miller Lite by Miller
•Bud Light by Budweiser
•Coors Light by Coors
Extra Light Lager
•MGD 64 by Miller
•Select 55 by Budweiser
©TheBeerLife

Beer Volatiles









Flavor Perception

- Volatiles have to be released from the beer
- Not uniformly released
- Release dependent on:
  - » Concentration
  - » Interactions with non-volatile ingredients

Previous Studies

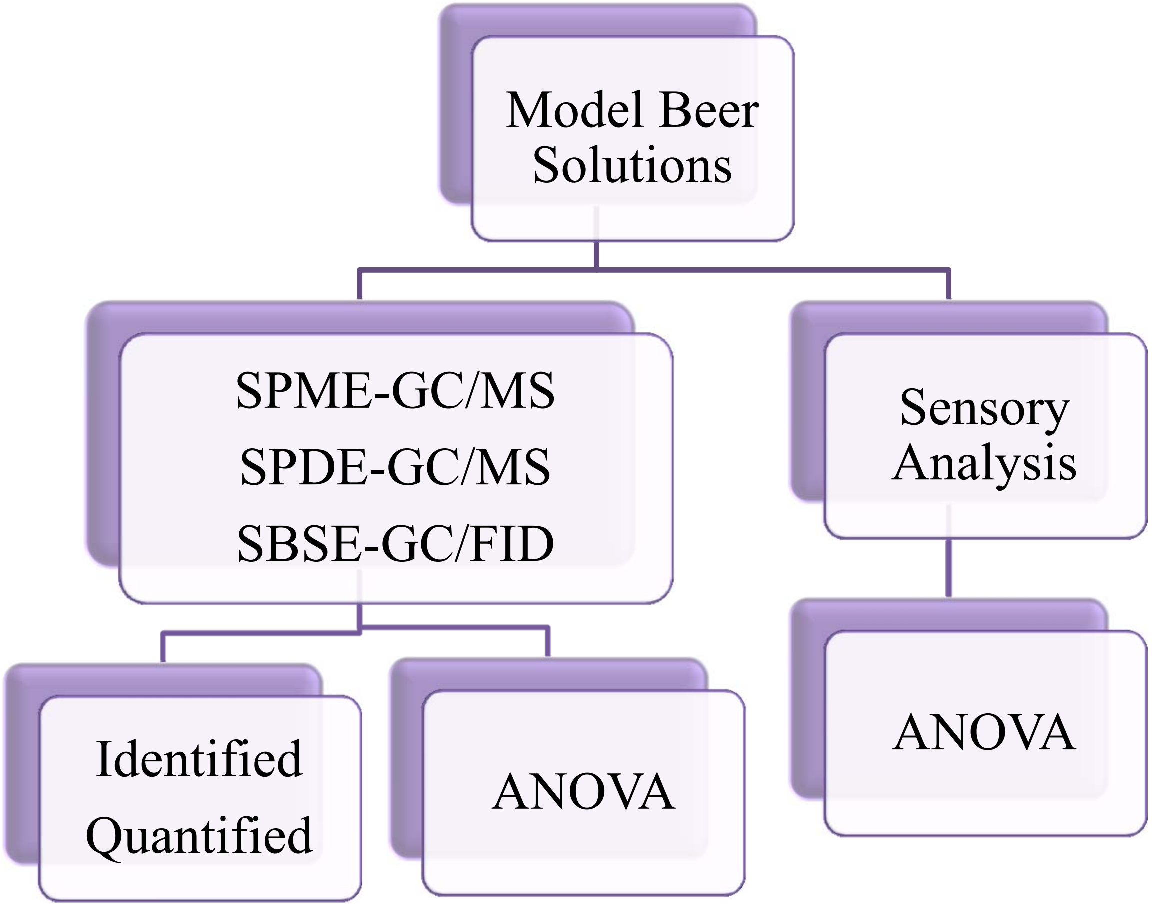
- Interactions among volatile aroma compounds and the non-volatile matrix influence flavor perception

- Relationships between chemical and sensory data would help understand how interactions affect flavor perception

OBJECTIVES

- Study the effect of non volatile levels on volatile fraction behavior and sensory perception
- Hypothesis: Interaction between volatile and non-volatile fractions will impact partitioning and sensory perception of the beer

EXPERIMENTAL APPROACH



Trained Panel

- 8 hour training sessions
- 15 cm-line scales
- Formal evaluations
- Aroma and Flavor perception

Synthetic Beer

- Beer Flavor Solution
- Non-Volatiles
- Isomerized Hop Acid

Synthetic Beer

Beer Flavor Solution

- Isoamyl acetate (Banana)
- Ethyl hexanoate (Apple)
- Benzaldehyde (Almond)
- Myrcene (Dry-Hop)

Non-Volatiles

- Glucose
- Fructose
- Maltodextrin
- Protein Extract

Synthetic Beer

Synthetic Beer

- 3 levels of CHO (Low, Medium, High)
- 3 levels of Pro (Low, Medium, High)
- 9 combinations of CHO/Pro

Sensory Results

Attribute	Protein Level L	Protein Level M	Protein Level H	Carbohydrate Level L	Carbohydrate Level M	Carbohydrate Level H
Apple aroma	3.7[a]	4.8[b]	5.0[b]	4.2[a]	4.7[a]	4.5[a]
Banana aroma	2.4[a]	3.4[b]	3.4[b]	3.1[a]	3.1[a]	3.0[a]
Almond aroma	2.5[a]	2.9[a]	2.8[a]	2.8[a]	2.6[a]	2.9[a]
Dry-Hop aroma	3.1[a]	2.9[a]	2.9[a]	3.4[a]	3.2[a]	2.5[b]
Apple flavor	3.3[a]	4.1[a]	3.8[a]	3.4[a]	4.0[a]	3.9[a]
Banana flavor	2.1[a]	2.6[a]	2.6[a]	2.2[a]	2.4[a]	2.6[a]
Almond flavor	3.3[a]	3.2[a]	2.9[a]	2.9[a]	3.1[a]	3.4[a]
Dry-Hop flavor	3.1[a]	2.9[a]	2.7[a]	3.4[a]	2.8[ab]	2.6[b]

Sensory Aroma Results

- Unexpected increase in aroma intensity with increasing levels of protein

- Proteins bind volatile flavor components

Aroma Results

- Presence of protein-protein interactions
- Retention varies depending on volatile compound
- Reciprocal aroma suppression

Reciprocal Aroma Suppression

- An odorant decreases the perceived intensity of others
- Suppression effect was reduced due to binding
- Processing of mixtures by the brain is not fully understood

Aroma Results

- Dry-hop reduction with increase in carbohydrate concentration
- Increase in solution hydrophobicity
- Myrcene hydrophobicity

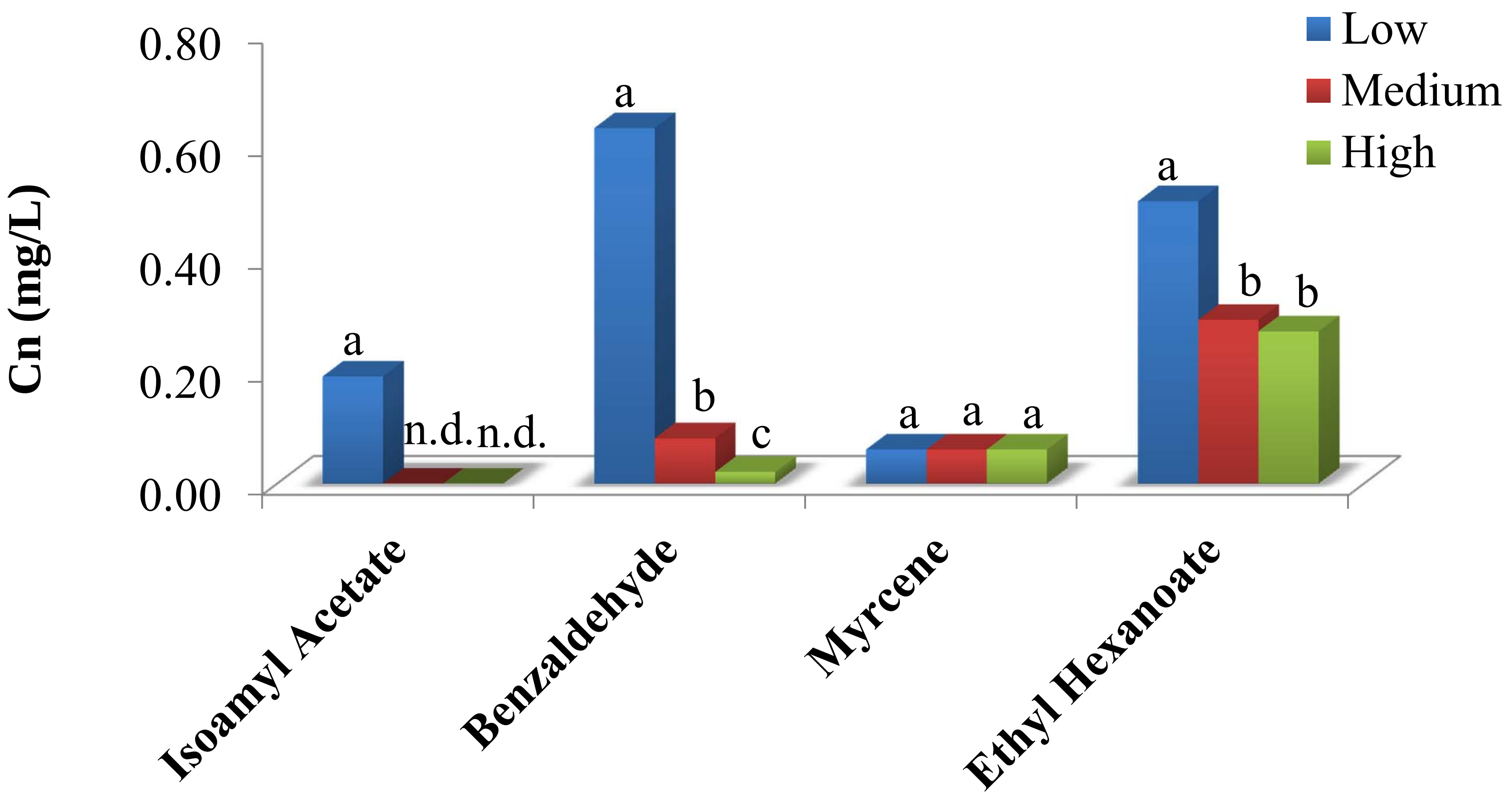
Flavor Results

- No trend in the results
- No effect except for dry-hop flavor
- Components in saliva could affect partitioning
- Individual panelist differences

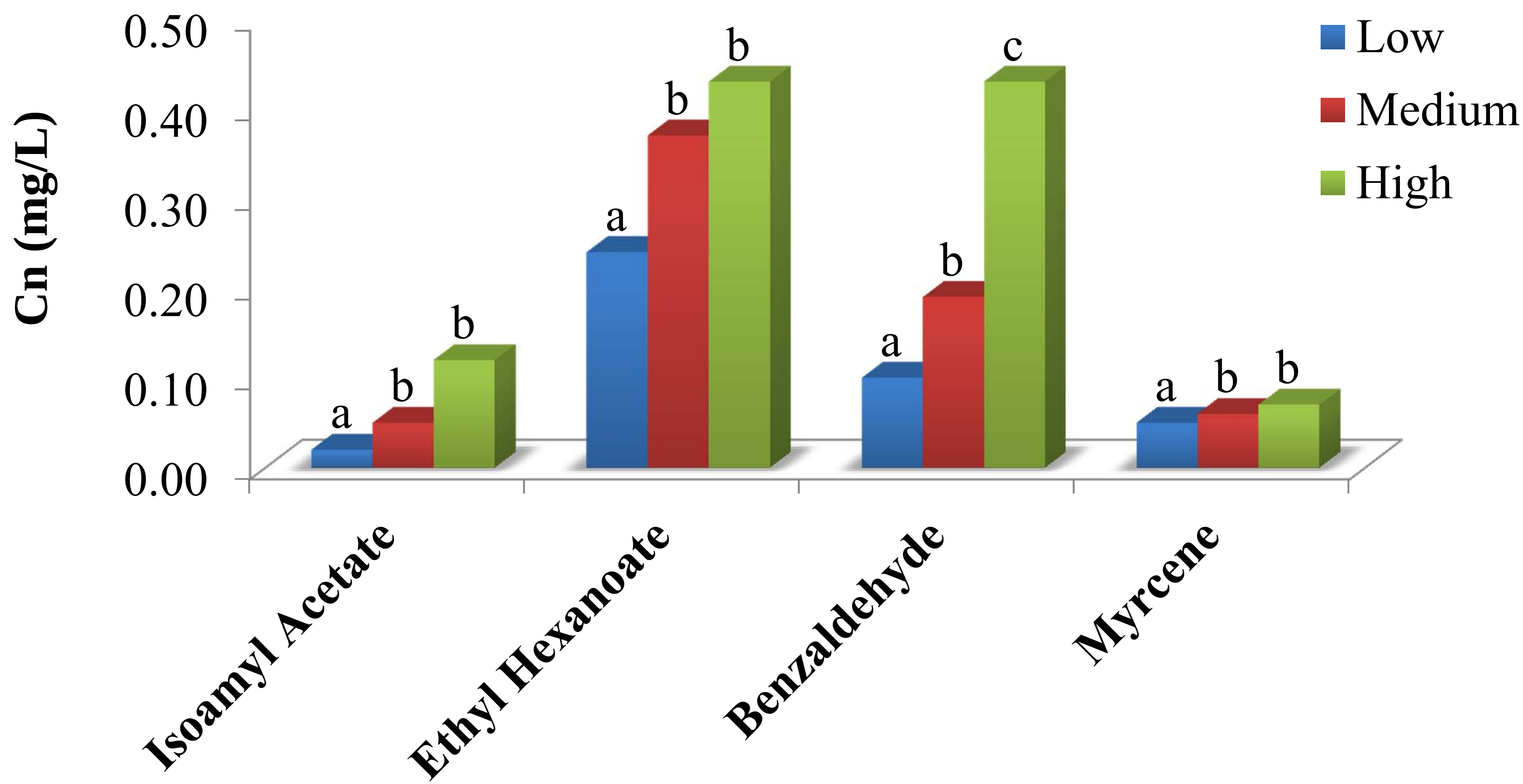
Instrumental Analysis

SPDE SBSE SPME

Concentration (mg/L) of Compounds at Different Protein Concentrations using SPME



Concentration (mg/L) of Compounds at Different CHO Concentrations using SPME



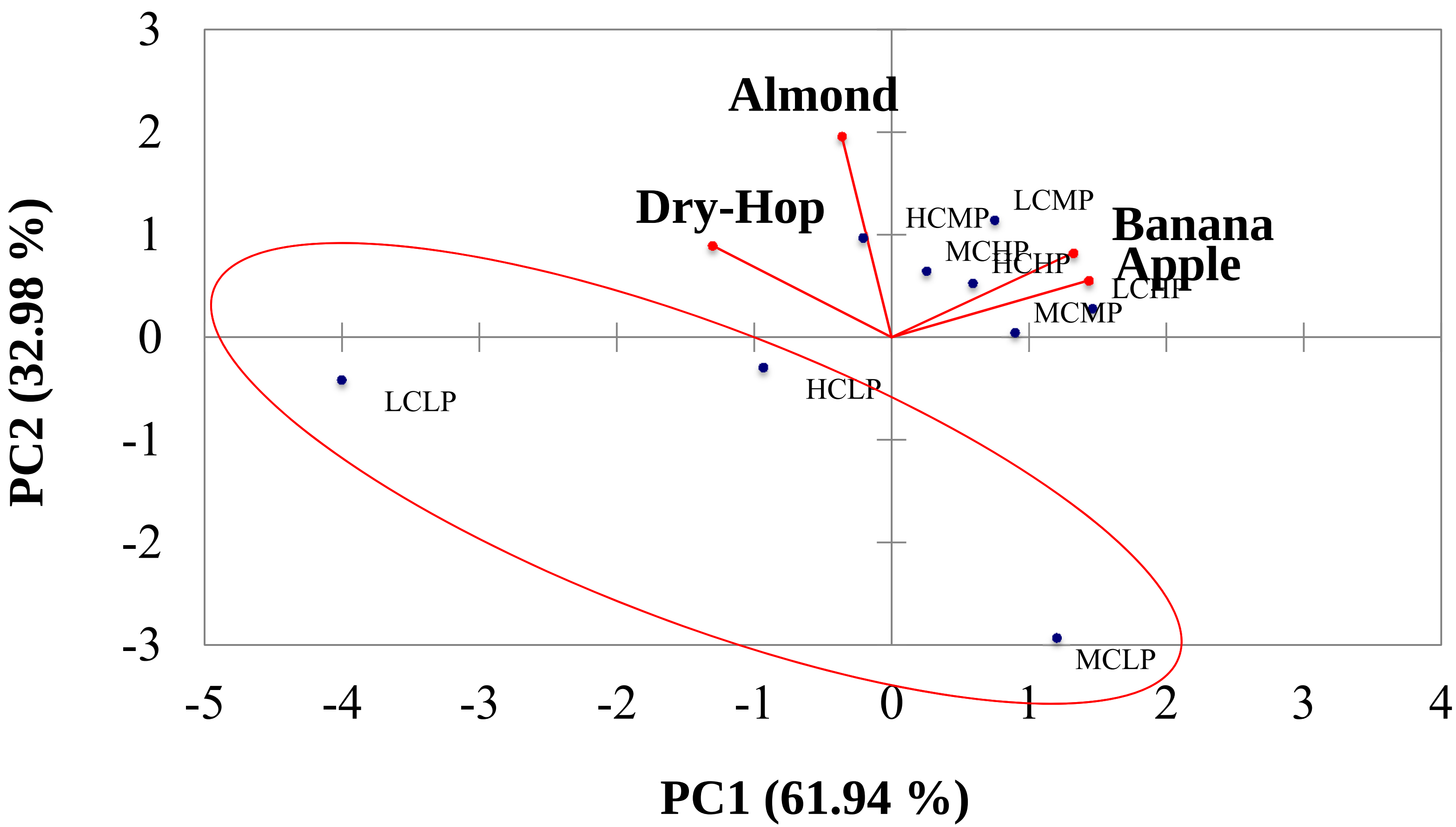
Proteins

- Proteins bind flavor compounds strongly
- Hydrophobic bonding
- High affinity of carbonyls to proteins
- Expected to find lower concentrations of compounds in headspace

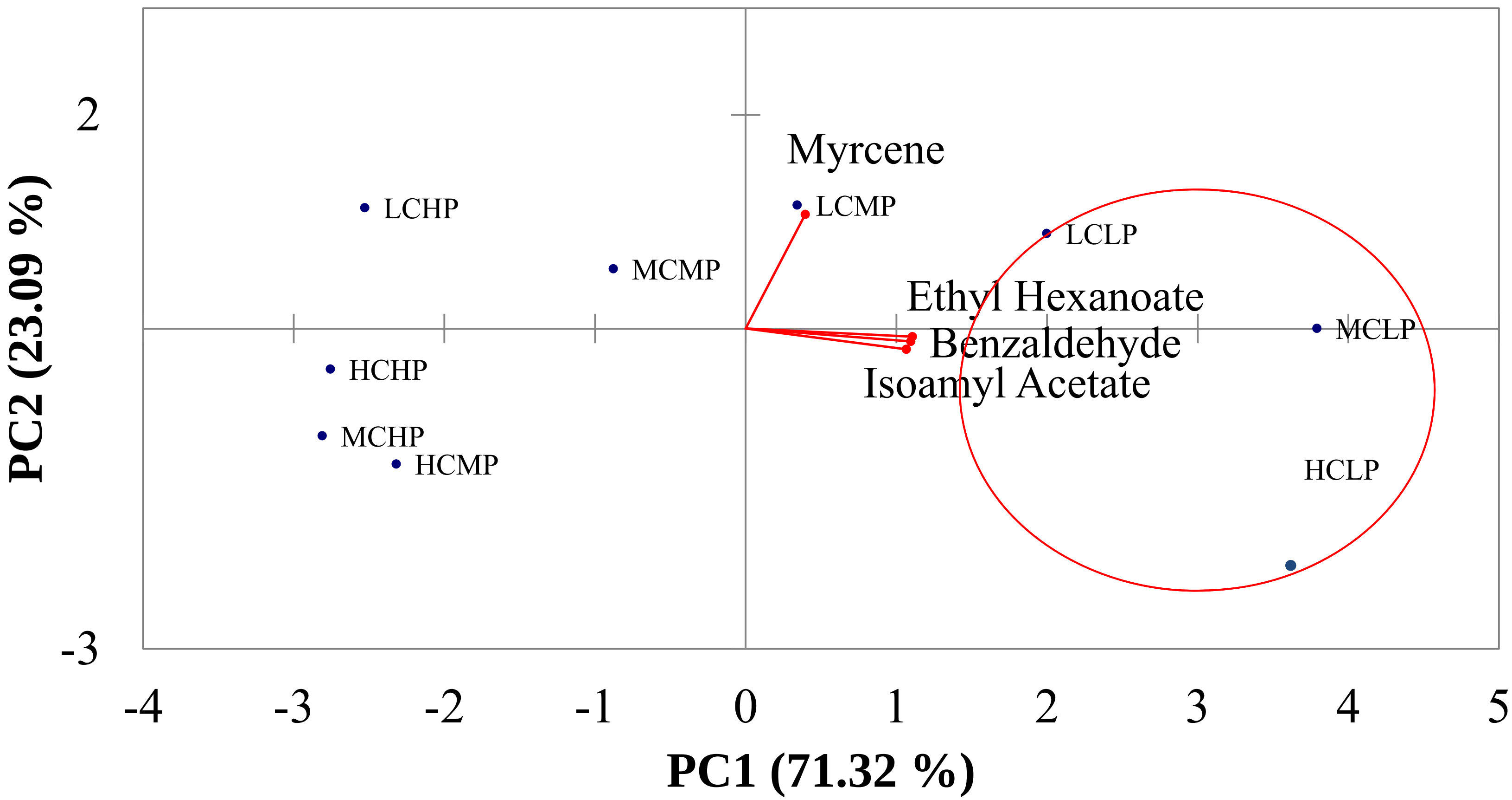
Carbohydrates

- Main effect due to modification of solutions viscosity
- Moderate effect due to molecular interaction
- Both retention and salting out effects have been observed

PCA Aroma Data



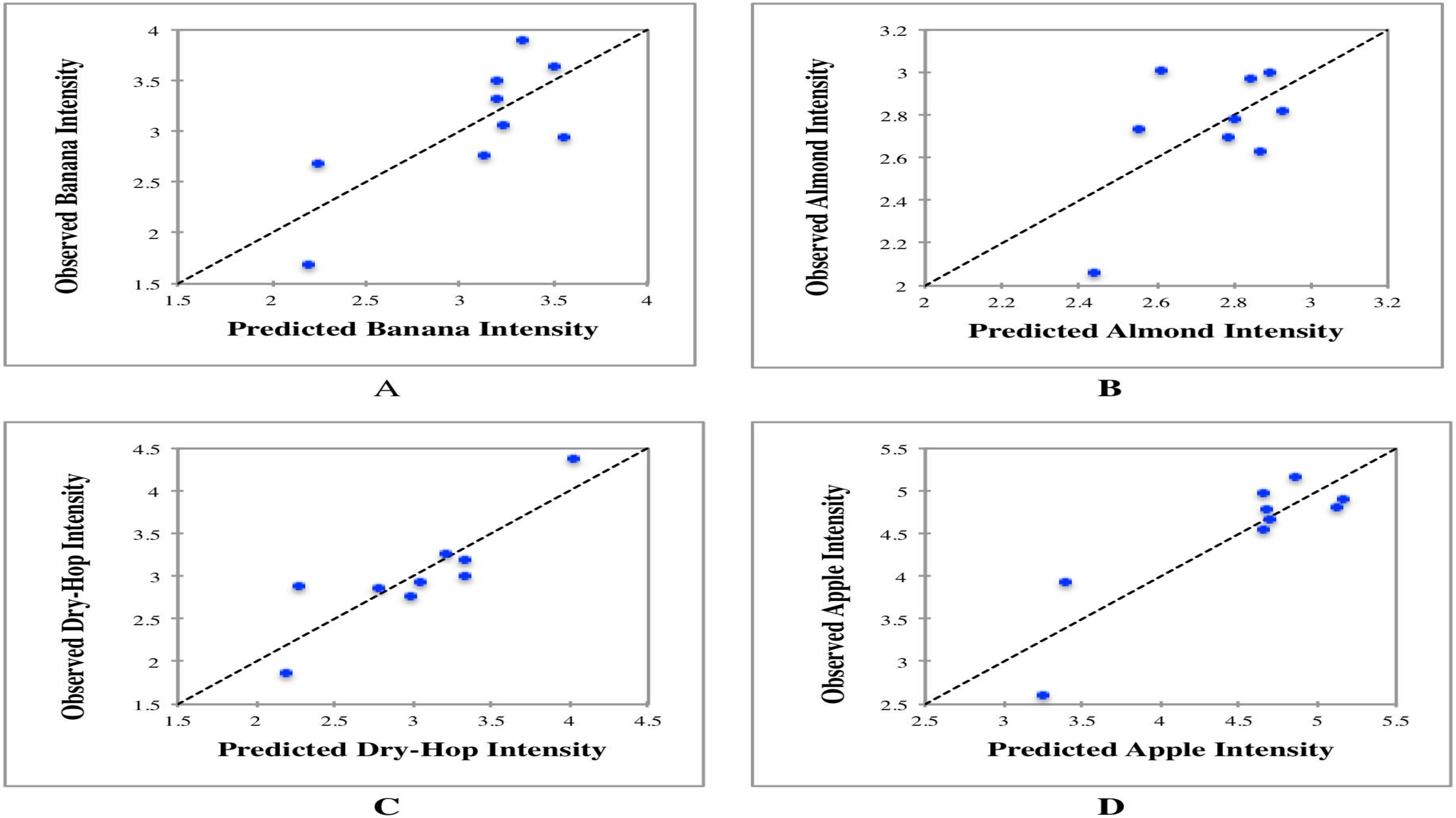
PCA SBSE Data




GERSTEL
MPS

Partial Least Squares Regression

- Used for predicting sensory data from instrumental data
- Creates linear models to relate Y to X
- Creates models to predict Y from X



PLS models to predict aroma sensory data for (A) banana, (B) almond, (C) dry-hop and (D) apple from instrumental data obtained by SBSE-GCFID analysis

R^2 and Q^2 values of the models to predict aroma sensory descriptive data

Attribute	SBSE R^2	SBSE Q^2	SPME R^2	SPME Q^2	SPDE R^2	SPDE Q^2
Banana	0.583	0.162	0.209	0.042	0.595	0.195
Almond	0.351	-0.076	0.180	-1.036	0.558	-0.044
Dry-Hop	0.755	-0.279	0.074	-0.540	0.963	-0.218
Banana	0.775	0.205	0.141	0.075	0.850	0.267

Observations

$\neq$

CONCLUSIONS

- Non-volatile fraction of model beer solutions influenced the volatile fraction behavior and sensory perception of the beverage

- Proteins played a bigger role in sensory perception than carbohydrates

- Results differed between the instrumental and the sensory results

CONCLUSIONS

- The PLS results indicated a weak correlation between the sensory and the instrumental data
- The results question the validity of directly relating instrumental data to sensory evaluation

CONCLUSIONS

- PCA showed clear differentiation among model beer samples mainly driven by the protein concentration

- Chemical volatile analysis can provide valuable information about volatile composition but it is not able to provide a complete flavor profile for beer

THANK YOU!!!!!