Evaluation of Florida-Grown Barley for Brewing Applications via Fermentability and Volatile Compounds

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Nick Wendrick[1], Jonathan K Lee[1], Mandi Chen[2], Pedro Ribeiro[2], Megan Kinsman[1], Charles E Barrett[3], Lincoln Zotarelli[4], Katherine Witrick[1] and Andrew MacIntosh[1]

[1]Food Science and Human Nutrition, University of Florida, Gainesville, FL, [2]Chemical Engineering, University of Florida, Gainesville, FL, [3]University of Florida, Gainesville, FL, [4]Horticultural Science, University of Florida, Gainesville, FL

Introduction and Objective

Florida's craft brewing industry currently produces 1.2 million barrels of beer, at a value of $3.8 billion, ranking 4th overall in the united states. The demand for beer and subsequently the barley/malt used to produce the beer are not currently produced in Florida requiring the importation of this key ingredient. Cultivation of Florida grown barley has the potential to provide breweries with local ingredients that many consumers appreciate and value leading to increased revenue and growth. Overcoming the lack of good practices for successful cultivation of barley in Florida is currently one of the biggest challenges. The University of Florida is investigating the production of these ingredients providing brewers a locally grown option of raw materials. The production of barley in Florida requires an understanding of the characteristics of the barley. These characteristics include the yield, overall sugar content, soluble solids, fermentation rate of the barley, final attenuation, yeast behavior during fermentation, and volatile profile of the wort and beer. This study specifically examined the fermentation rate, final attenuation, yeast behavior during fermentation, and volatile profile of the wort and beer of eight Florida grown barleys compared to a commercial Copeland variety malt from Skagit Valley Malting (SVM). **The objective of this study was to assess suitable barley varieties to grow in Florida for brewing applications by examining the fermentability, and concentration of semi-volatile and volatile compounds of the wort and beer produced.**

Materials and Methods

- Barley was finely ground into a powder then mashed using the European Brewing Convention (EBC) congress mash method.
- Wort was autoclaved for sterility then the sugars were adjusted to the same concentration of 12°P.
- A two-day yeast grow up and propagation was completed using ASBC Yeast-14 method and Diamond lager yeast.
- Fermentation parameters including sugar concentration and yeast measurements were monitored using ASBC Yeast-14 .
- Sugar and yeast measurements were plotted using Graphpad Prism and a non-linear curve was fit to the model.
- Wort and beer samples were saved for volatile analysis using a Solid-Phase Microextraction (SPME).
- A Shimadzu Gas Chromatograph with Mass Spectrometer (GC-MS) with a ZB-5MS column was used for separation of volatile compounds then analyzed using retention time along with Wiley 2014 mass spectral library.
- Identification of volatile compounds was performed using RI values and compared to literature values.

Figure 1. Yeast-14 test tube fermentations of FL barley and control.

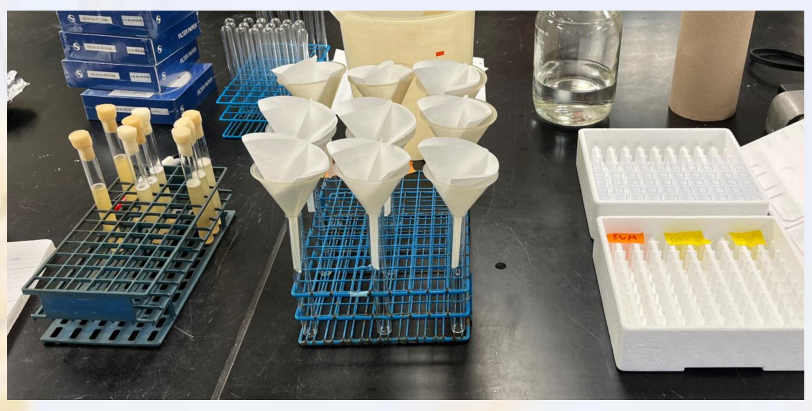

Figure 2. Yeast-14 measurements of extract and absorbance performed in triplicate.

Figure 3. Shimadzu Gas Chromatograph (GC) 2010 plus series with mass spectrometer detector (MSD) used for volatile analysis of wort and beer samples.

Discussion

Each starting wort was standardized to 12°P by first diluting to 8°P then raising to the starting gravity using dextrose. Following the standard yeast grow up outlined in Yeast-14, the yeast were pitched at a rate of 15 million cells/mL by first inoculating the flask of wort then dispensing 15mL into test tubes. Each curve was built using 10 sampling times over the course of 130 hours. The SVM control malt was compared to each of the Florida grown barley varieties for sugar consumption and yeast in suspension. The final attenuation of the SVM was 0.28 ± 0.12 compared to the two best performing Florida grown barley varieties being Copeland and Esma with final attenuation of 1.51 ± 0.20 and 1.92 ± 0.12, respectively. However, the SVM performed significantly better than all the Florida grown barley varieties. The worst performing variety was Odyssey with a final attenuation of 3.47 ± 1.29 indicating Premature Yeast Flocculation (PYF). The remaining five Florida grown barley varieties had a final attenuation between two and three Brix. The sugar consumption demonstrates that each barley variety possess different fermentability characteristics. The yeast in suspension were measured spectrophotometrically at 600nm providing insight into the fermentation kinetics. The SVM control malt performed significantly better than all of the Florida grown barley samples. The area under the curve was used to evaluate the fermentation with the best Florida barley samples resulting in Esma and Pinnacle. The worst producing barley varieties based on yeast in suspension were Conlon and Odyssey supporting the theory that some of the barley varieties suffered from PYF. The Volatile Organic Compounds (VOCs) were analyzed in both the wort and beer. The compounds identified using SPME coupled with GC-MS were organized based on chemical class into alcohols, aldehydes, benzenes, ketones, acids, and esters. Seventeen VOCs were identified in the wort samples with two compounds having significantly different concentrations. Isovaleraladehyde is characteristic in malted barley as the concentration in the unmalted Florida barley samples was significantly lower. In the beer samples, twenty-four VOCs were identified with four compounds being statistically significant. There was little difference in the VOCs present between the Copeland and Esma barley samples with only decanal being significantly higher. Heptanol, phenylethyl alcohol, and phenethyl acetate were significantly higher in the SVM control malt compared to Esma barley. Overall, the VOCs were not substantially different between the commercial control malt and the two Florida barley samples tested in both the wort and beer.

Conclusion and Future Work

- The Copeland and Esma barley had the highest performance of all eight barley varieties with a final attenuation of 1.51 ± 0.20 and 1.92 ± 0.12 °P, respectively.
- Final attenuation correlated with the number of yeast in suspension throughout fermentation.
- Seventeen volatile compounds were identified in SVM and Florida barley wort samples, two of which were statistically significant between samples but not substantially different in concentrations.
- Twenty-four volatile compounds were identified in SVM and Florida barley beer samples, four of which were statistically significant between samples.
- These research findings have the potential to positively impact the Florida brewing industry through evaluation of Florida grown barley and locally produced beer.

Acknowledgements

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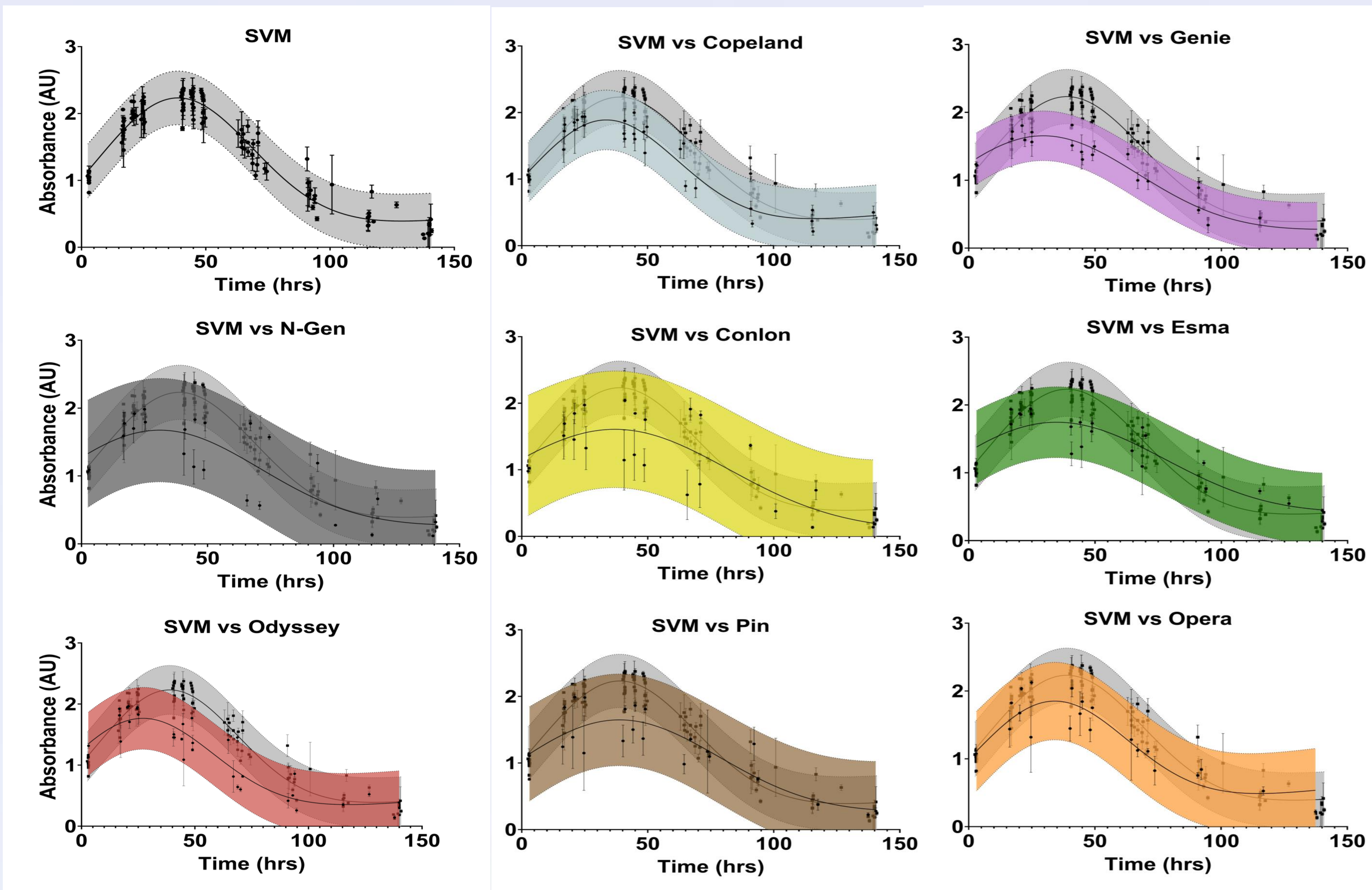
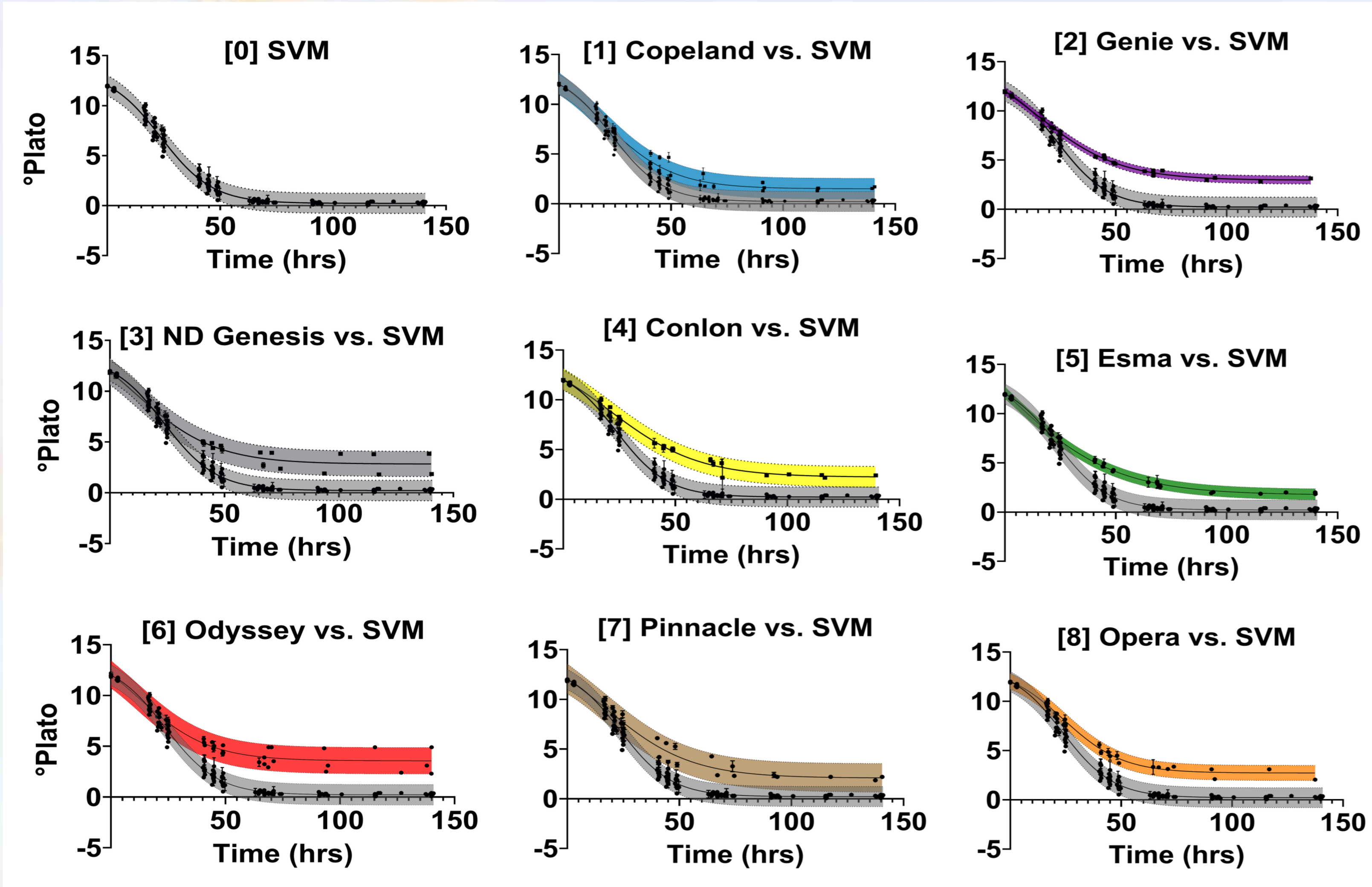
Results





			Approximate Concentrations (mg/L)		
Compound	LRI	Descriptor	SVM control	Copeland barley	Esma barley
Alcohols	-	-	0.50 ± 0.21	0.41 ± 0.10	0.47 ± 0.21
2-Furanmethanol	864	burnt	0.20 ± 0.09 a	0.13 ± 0.01 a	0.26 ± 0.18 a
Heptanol	975	mushroom, chemical, green	0.08 ± 0.03 a	0.09 ± 0.03 a	0.12 ± 0.02 a
2-Ethyl-1-hexanol	1029	citrus, fresh, floral	**0.03 a**	**0.07 ± 0.00 b**	ND ± ND
1-Octanol	1069	moss, nut mushroom	0.03 ± 0.01 a	0.04 ± 0.01 a	0.03 ± 0.01 a
Maltol	1073	carmel, baked bread	0.16 ± 0.08 a	0.05 ± 0.03 a	ND ± ND
1-Nonanol	1169	fatty, bitter, orange	ND ± ND	0.03 ± 0.01 a	0.06 ± 0.01 a
Aldehydes	-	-	3.30 ± 1.29	1.95 ± 0.78	1.15 ± 0.49
Isovaleraldehyde	704	fruity, rancid, sweaty	**1.57 ± 0.60 b**	0.75 ± 0.17 ab	**0.10 ± 0.05 a**
Hexanal	807	green	0.20 ± 0.04 a	0.15 ± 0.05 a	ND ± ND
Furfural	834	bread, almond, sweet	0.35 ± 0.16 a	0.27 ± 0.12 a	0.11 ± 0.08 a
Heptanal	903	fat, citrus, rancid	0.25 ± 0.07 a	0.11 ± 0.05 a	0.23 ± 0.08 a
Phenylacetaldehyde	1043	green	0.35 ± 0.05 a	0.34 ± 0.21 a	0.19 ± 0.05 a
Nonanal	1098	citrus, fatty, rose	0.13 ± 0.09 a	0.12 ± 0.09 a	0.09 ± 0.02 a
Decanal	1204	sweet, citrus, floral	0.14 ± 0.03 a	0.13 ± 0.07 a	0.09 ± 0.01 a
5-Hydroxymethylfurfural	1221	fatty	0.31 ± 0.25 a	0.08 ± 0.03 a	0.33 ± 0.19 a
Benzene	-	-	0.12 ± 0.04	0.11 ± 0.09	0.12 ± 0.04
Naphthalene	1185	medicinal	0.12 ± 0.04 a	0.11 ± 0.09 a	0.12 ± 0.04 a
Ketones	-	-	0.13 ± 0.08	0.16 ± 0.08	0.17 ± 0.04
2-Heptanone	894	soap	ND ± ND	0.08 ± 0.01 a	0.07 ± 0.04 a
2-Octanone	993	floral, green, earthy	0.13 ± 0.08 a	0.08 ± 0.07 a	0.10 ± 0.00 a

			Approximate concentrations (mg/L)		
Compound	LRI	Descriptor	SVM control	Copeland barley	Esma barley
Acid	-	-	0.54 ± 0.28	0.40 ± 0.18	0.47 ± 0.09
Hexanoic acid	996	fatty, sweat	0.12 ± 0.11 a	0.14 ± 0.10 a	0.19 ± 0.03 a
Octanoic acid	1172	fatty	0.38 ± 0.16 a	0.21 ± 0.06 a	0.28 ± 0.05 a
Decanoic acid	1347	rancid, fat	0.04 ± 0.01 a	0.05 ± 0.02 a	ND ± ND
Higher Alcohols	-	-	34.16 ± 7.17	28.62 ± 2.84	30.60 ± 3.29
Isopentyl alcohol	752	whiskey, malt, burnt	27.05 ± 5.84 a	24.10 ± 1.92 a	26.53 ± 2.76 a
2-Methyl-1-butanol	771	malt	0.40 ± 0.17 a	0.23 ± 0.04 a	0.28 ± 0.05 a
2-Furanmethanol	864	burnt	0.10 ± 0.07 a	0.11 ± 0.04 a	0.05 ± 0.05 a
Heptanol	975	mushroom, chemical, green	**0.16 ± 0.01 b**	0.14 ± 0.02 ab	**0.12 ± 0.01 a**
2-Ethyl-1-hexanol	1029	citrus, fresh, floral	0.08 ± 0.02 a	0.12 ± 0.01 a	0.11 ± 0.05 a
1-Octanol	1069	moss, nut mushroom	0.16 ± 0.03 a	0.21 ± 0.02 a	0.18 ± 0.00 a
2-Nonanol	1097	fatty	0.02 ± 0.01 a	0.04 ± 0.01 a	0.05 ± 0.03 a
Phenylethyl Alcohol	1108	floral	**6.19 ± 1.03 b**	**3.49 ± 0.73 a**	**3.10 ± 0.33 a**
1-Nonanol	1169	floral	ND ± ND	0.19 ± 0.04 a	0.19 ± 0.01 a
Aldehydes	-	-	0.36 ± 0.10	0.44 ± 0.13	0.65 ± 0.34
Nonanal	1100	fat, citrus, green	0.15 ± 0.05 a	0.13 ± 0.03 a	0.21 ± 0.10 a
Decanal	1205	soap, tallow, orange	**0.07 ± 0.02 a**	**0.10 ± 0.02 b**	**0.09 ± 0.03 a**
5-Hydroxymethylfurfural	1221	fatty	0.14 ± 0.02 a	0.22 ± 0.08 a	0.35 ± 0.21 a
Benzene	-	-	0.19 ± 0.02	0.17 ± 0.05	0.15 ± 0.06
Naphthalene	1185	medicinal	0.19 ± 0.02 a	0.17 ± 0.05 a	0.15 ± 0.06 a
Esters	-	-	15.79 ± 4.20	13.16 ± 4.01	13.02 ± 3.10
Isoamyl acetate	882	banana	5.85 ± 1.44 a	5.28 ± 1.33 a	3.51 ± 0.19 a
n-Hexyl acetate	1015	fruit, herb	0.05 ± 0.01 a	0.08 ± 0.06 a	0.04 ± 0.01 a
Ethyl hexanoate	1001	apple peel, fruit	0.97 ± 0.50 a	0.80 ± 0.69 a	0.75 ± 0.52 a
Ethyl heptanoate	1092	fruit	0.05 ± 0.02 a	0.14 ± 0.06 a	0.19 ± 0.11 a
Ethyl octanoate	1196	fruit, fat	4.40 ± 1.29 a	4.26 ± 1.25 a	5.95 ± 1.45 a
Phenethyl acetate	1249	rose, honey, tobacco	**2.91 ± 0.63 b**	**1.36 ± 0.34 a**	**0.86 ± 0.20 a**
Ethyl 9-decenoate	1372	fruity	0.87 ± 0.25 a	0.64 ± 0.19 a	0.87 ± 0.34 a
Ethyl decanoate	1381	grape	0.68 ± 0.06 a	0.60 ± 0.08 a	0.85 ± 0.28 a