

Fugacity Brewing

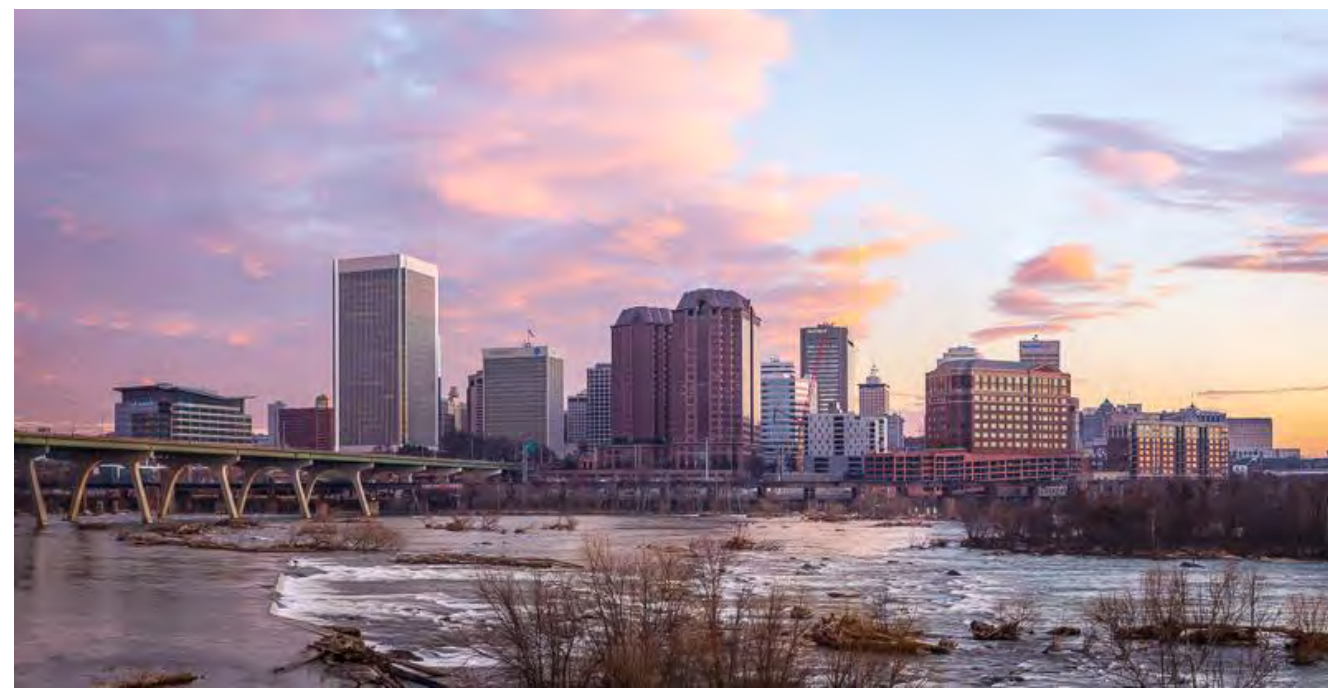
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 Tidewater AICHE Local Section, Richmond, VA
 2019 AICHE Beer Brewing Competition, Orlando, FL

Brewing Contest Challenge

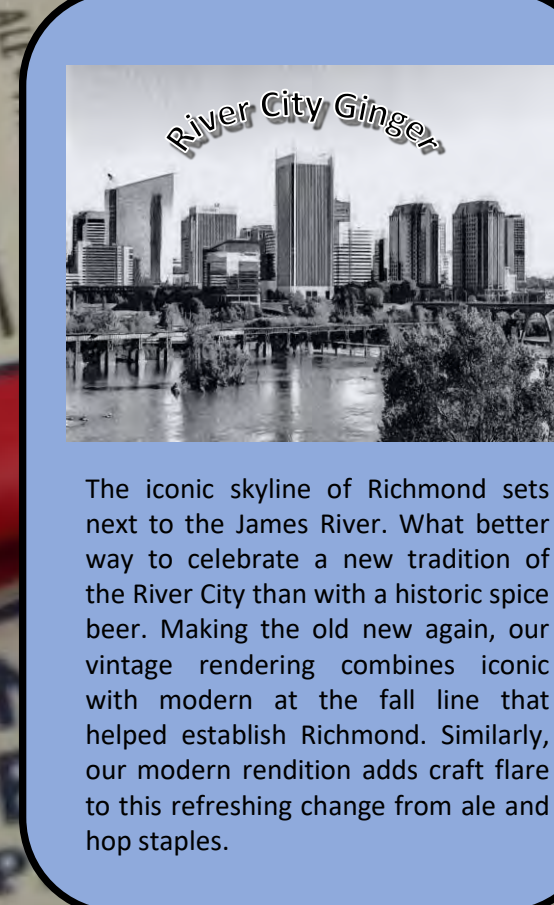
One of the appealing aspects to the brewing process is that process ingredients are edible. Grist is the backbone for any beer, see if you can identify BJCP categories of these three milled grists and we might have a prize for you!

Introduction

The Tidewater Local Section is based out of Richmond Virginia, a vibrant and diverse city known for arts, a renown 'River-City' culture and one of America's top rated beer scenes [1]. With passion for great beers and the complimenting skills that Chemical Engineers bring to the beverage industry, we have come together to build professional comradery, support new chemical engineering relationships and embrace the science and art of an emerging industry. Our goal has been to develop quality recipes and processes for styles of beer that our team is interested in, while having fun! **



The details of our entries are include to the right and below. From left to right we present a label with enticing description, in the middle you will find some history and details of each category with vital statistics and overview of characteristics of our entries with brewing efficiency details. To the right we have images of our fresh beers before bottle conditioning. At the very bottom are mass balance details.



The iconic skyline of Richmond sets next to the James River. What better way to celebrate a new tradition of the River City than with a historic spice beer. Making the old new again, our vintage rendering combines iconic with modern at the fall line that helped establish Richmond. Similarly, our modern rendition adds craft flare to this refreshing change from ale and hop staples.

Ginger Beer Entry: River City Ginger (30A, Spice Herb or Vegetable Beer - Ginger Beer)

Ginger emerged via the spice trade with the Orient, supplies were controlled by the Middle East after fall of the Roman Empire, leading to growth in tropical areas (e.g. the Caribbean) First reports of use in fermented beverages occurred in England in the mid-1700's. Original beer were grown from a symbiotic culture of yeasts and bacteria a.k.a. 'ginger beer plant' described in appearance as jellied crystal. In reality, colonies of microorganisms surround yeast in a symbiotic relationship, where ethanol produced by yeast feeds the microbial consortia. Two microorganisms responsible for a traditional ginger beer's character, i.e. creamy toffee, have been cited as *Saccharomyces pyiformis* and *Brevibacterium veriforme*. As we explore new styles to brew, we opted for a lighter beer (Wheat/Spice) settling in on the non-traditional means of making a Ginger Beer that we thoroughly enjoy. We liken our entry to be reminiscent of a Sprite with an alluring opaque white appearance that tickles your nose with a high amount of carbonation.

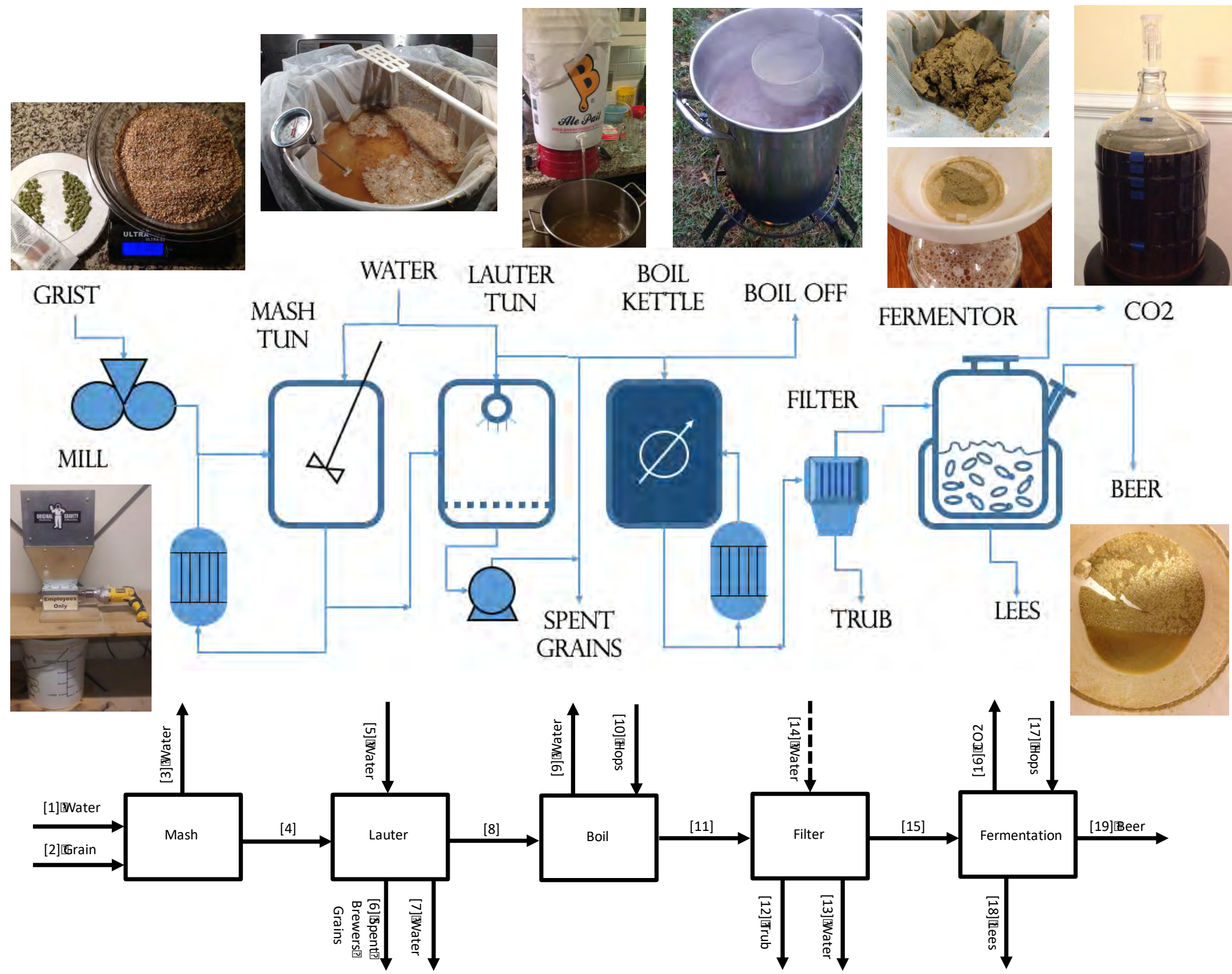
Vital Statistics:
 IBUs: 16 - 26
 SRM: 6 - 25

OG: 1.072 - 1.112
 FG: 1.016 - 1.024
 ABV: 7.0 - 10.0%

O.G.	1.100
F.G.	1.030
ABV	9.20



"Nano-Brewing" Process Flow



Indian Pale Ale Entry: Just Sit (21B, Specialty IPA: New England IPA [5])

The 'New England' style is named for its origin region first attributed to Alchemist's Heady Topper. Typically light in color, the style appears hazy with a light to moderate and smooth mouthfeel. Hop character is less bitter than a West coast style with focus on aroma and depth including tropical or stone fruit and citrus. Our entry follows an all grain recipe with flaked wheat and flaked oats to impart a hazy appearance and smooth mouthfeel. Several hop additions from the boil to late fermentation impart a spicy bitterness, tropical fruit aroma inline with the the emerging classic characteristic of this style, and a strong grapefruit finish, making this beer a juicy double IPA that you will want to 'Just Sit', and enjoy!

Original Gravity	Final Gravity	ABV	IBU	SRM
1.071	1.015	7.35%	40.39	4.71

Wort (=) gal	2.25
OG	1.075
FG	1.017
Points (sugar extraction)	168.75
Points / lb.	25.96
Brew Efficiency	0.705

IBU	25 - 60
SRM	3 - 7
OG	1.080 - 1.085
FG	1.010 - 1.015
ABV	6% - 9%

Grist	lbs	%	Max ppg est*	Max Grn Pts
US 2-row malt	4.5	0.69	37.00	74.00
UK Golden Promise	1	0.15	37.50	16.67
Flaked Wheat	0.5	0.08	36.00	8.00
Flaked Oats	0.375	0.06	37.00	6.17
Acidulated malt	0.125	0.02	27.00	1.50
SUM	6.5	100		106.33



Indian Pale Ale Entry: The Friesian (21B, Specialty IPA: Black IPA)

A Black IPA is also referred to as a Cascadian Dark Ale (CDA) and its creation is attributed to craft brewery pioneer and patriot: Greg Nonoona [7]. The style is supposed to represent the mix of a stout or porter with an IPA, hinting at the myriad possibilities of combinations. We marry cultures with a complex C-type hopping schedule, a 'dry' grist fermented to maintain residual sweetness with an English yeast strain known for its own nature to enhance rich complexity. If you aren't afraid to 'Knight-Up' and mount the Friesian, we are confident your experience will be limited only by your imagination.

Original Gravity	Final Gravity	ABV	IBU	SRM
1.080	1.022	7.59%	77.26	39.8

Wort (=) gal	2.65
OG	1.082
FG	1.0215
Points (act. Sugar extraction)	217.3
Pts./lb	24.89
Brew Efficiency	0.71

IBUs	50 - 90
SRM	25 - 40
OG	1.050 - 1.085
FG	1.010 - 1.018
ABV	5.5 - 9.0%

Grist	lbs	%	Max ppg est*	Max Grn Pts
Maris Otter (Crisp UK)	5	57.3	35	66.0
Pale Ale (UK Crisp 2 row, 2.5 - 3.5L)	1	11.5	38	14.3
Munich (Crisp UK, 5.1 - 7L)	0.5	5.7	37	7.0
Rye Malt (German, 3.5L) huskless	0.5	5.7	39	7.4
Crystal rye (UK) ~ 70-80L	0.5	5.7	35	6.6
Carafa III (German, 535 L, huskless)	0.25	2.9	32	3.0
Flaked barley (Briess 1.4L)	0.5	5.7	32	6.0
Midnight wheat (Amer or Breiss 550 L)	0.28	3.2	33	3.5
Carapils	0.2	2.3	30	2.3
SUM	8.73	100		116.1



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 - <https://www.bostonmagazine.com/restaurants/2013/04/22/liquid-diet-the-new-black/>
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Mass Balances and Brewing Efficiencies

Stream	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Description	Mash Water	Grist	Water Off	Mass to Lauter	Sparge Water	Sat BSG	Lauter Mass	Mass to Boil	Boil Water	Evap	Boil Hop	Post Boil	Wet Trub	Filter Water	Loss	Water Adds	Wort to Fer	Dry Hop	Lees Beer
NEIPA	22.96	7.3	0.85	28.33	14.61	8.5	1.95	32.45	1.93	0.1875	30.71	0.68	0	0	2.65	0.70	0.0625	1.837	1.97
Black IPA	22.13	8.7	0.63	29.44	14.61	10.2	2.01	31.82	1.42	0.25	30.65	0.82	0	2.75	2.65	0.67	0.0625	1.336	2.34
Ginger	41.75	8	-	-	-	-	-	49.75	0.41	NA	49.34	0.5	0	0	4.95	3.38	0	2	4.27

*** All upper table values are in pounds, except for 19 = 7 gallons

Parameter	NEIPA	Black IPA	Ginger
Sugar Extracted (SE)	1.59	1.81	8.00
Residual Sugars (RS)	0.20	0.48	1.24
SE/Met. (SEM)	1.39	1.34	6.76
Spent Brewers Grains	5.71	6.92	0
OG	1.072	1.082	1.1
FG	1.009	1.0215	1.03
Boil Time (min)	95	70	20

CONSTANTS	
Fermentor Weight (F)	9.04 lbs
Small Kettle (SK)	2.05 lbs
Large Kettle (LK)	4.71 lbs
Nylon Bag (NB)	0.2 lbs
Ale Pale (AP)	2.25 lbs

Estimated Values	
Boil Rate (BR)	1.218 gal/h
	0.0203 gal/min
Water Ab/lb Gs	1.4 lb/lb grain
MEV/BE ratio	0.44
WT/Gs	0.09



fugacity Brewing

"An Ideal Nanobrew"

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TAKE OUR BREWING QUIZ CHALLENGE!

We enjoy our rigorous physical science roots and celebrate with the name of our efforts. As a challenge to those taking an interest in our poster, name the inventor of the general thermodynamic relationship below and one use of equation in relationship to brewing science and engineering. Answers will be included in a drawing, and the first correct response will win a bottle of our season variant: Fester's Spicy Brew!

$$\log V_g^0 = c + rR_2 + s\pi_2^H + a\alpha_2^H + b\beta_2^H + 11\log L^{16}$$

INTRODUCTION

We are nano-brewers that enjoy creative presentation of flavor, visiting breweries, and imbibing refreshing beer while having fun! To us nano-brewing means that we refined our own 'small-scale' whole grain brewing process to standardize and explore the characteristics of our own beers. We are interested in continuing to build our expertise, launching our brewery, and incorporating science and engineering to compliment education programs we are a part of.

We entered both a Dark and Malty & a Bright and Hoppy entry to the first AIChE Beer Brewing Competition. Our Dark and Malty entry is a Foreign Extra Stout with a 'scary' variant for the Halloween holiday season. Our Bright and Hoppy entry is a take on the emerging New England style that is argued to belong to either the American IPA or Indian IPA category. This poster presents our Foreign Extra Stout entry: The Fugacity Foreign Extra Stout and a variant we call: "Scary Hot Mess".

Our 'Dark and Malty' Entry

Foreign Extra Stout

History: A classic beer in this category is the Foreign Extra Stout. Originally brewed as Guinness West India Porter from the St. James Gate area of Dublin Ireland, the Guinness Foreign Extra Stout has been made since the early 1800s. The category is known for higher hop and alcohol content that promoted stability to be sent abroad. Guinness is reported as establishing the West India Porter to ship beer to workers in the Caribbean markets (and hence, sometimes known as "Tropical Stouts") [1]. Our goal was not to try and clone any one beer but to create our own creamy complex stout in rapid fashion given our experiences. Examples of stouts the we do enjoy include the Guinness Extra Stout and the Strangeways Imperial Stout: Gourds of Thunder.

Ingredients (~ 2.5 gal fermentation):

Pale and dark roasted malts and grains.

Grain bill

- 4.25 lbs. Briess 2-row pale ale
- 0.5 lbs. Flaked barley
- 0.19 lbs. Briess Blackprinz
- 0.16 lbs. Briess caramel 40L
- 0.16 lbs. Briess caramel 60L
- 0.13 lbs. Briess flaked oats
- 0.13 lbs. Briess chocolate malt
- 0.13 lbs. Crisp (UK) roasted barley

Ale yeast (although some are brewed with lager yeast).

- RVA Yeast Labs #131 Chiswick Ale Yeast

Hops mostly for bitterness.

- 1 oz. Kent Goldings pelleted hops



Seasonal Variant

Our bigger variant adds spiciness and complex sugars intensity in line with the "Caribbean" style of a Foreign Extra Stout.

Our variant utilized post primary fermentation additions;

- Habanero
- 1 oz. dark Belgian candied sugar
- 1 tsp yeast nutrient

FOREIGN EXTRA STOUT

Category Description [2]

Aroma: Roasted grain aromas moderate to high, and can have coffee, chocolate and/or lightly burnt notes. Fruitness medium to high. Stronger versions can have the aroma of alcohol (never sharp, hot, or solventy). Hop aroma low. Diacetyl low.

Appearance: Very deep brown to black in color. Clarity usually obscured by deep color (if not opaque, should be clear). Large tan to brown head with good retention.

Flavor: Tropical versions can be quite sweet without much roast or bitterness, while export versions can be moderately dry (reflecting impression of a scaled-up version of either sweet stout or dry stout). Roasted grain and malt character can be moderate to high, although sharpness of dry stout will not be present in any example. Tropical versions can have high fruity esters, smooth dark grain flavors, and restrained bitterness; they often have a sweet, rum-like quality. The roasted flavors may taste of coffee, chocolate, or lightly burnt grain. Little to no hop flavor. Very low to no diacetyl.

Mouthfeel: Medium-full to full body, often with a smooth, creamy character. Moderate to moderately-high carbonation.

Overall Impression: A very dark, moderately strong, roasty ale. Tropical varieties can be quite sweet.

Comments: A rather broad class of stouts, these can be either fruity and sweet, dry and bitter. Think of the style as either a scaled-up dry and/or sweet stout, or a scaled-down Imperial stout without the late hops.

Pre-brewing Analysis

RVA yeast labs describes the #131 strain as follows;

- Flocculation: Very High
- Attenuation: 65-72%
- Suggested fermentation temperature: 65-70° F
- Alcohol Tolerance: Medium (8%)

We used the Brewer's Friend IBU Calculator for Beer Bitterness (image to right) [3].

We also used the Complete Recipe tool (images below) [4]. To match our initial gravity, the extraction efficiency is 97%, indicating that our nano-brewing process is highly efficient.

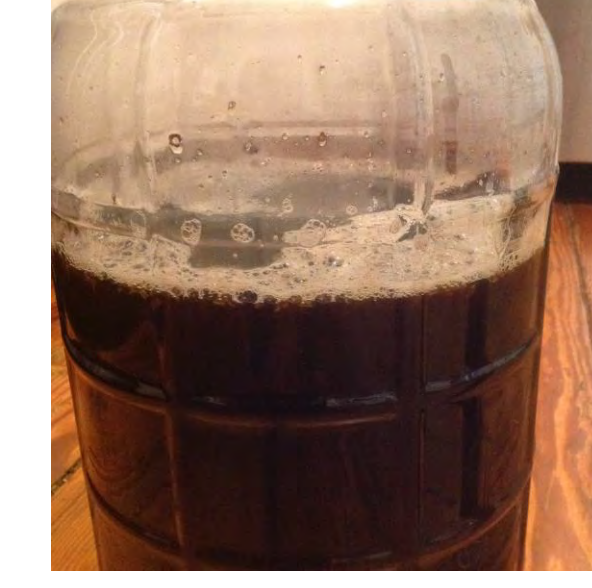
METHODS

Outline of Brewing Process

- 1) Collect and Prepare Grain Bill, Including Grain Mill
- 2) Ramp Temperature, 30 Minute
- 3) Single Infusion Mash (target 155°F)
- 4) Heat Sparge Water (150°F) and Remove Grains
- 5) Ramp Temperature to Boil
- 6) Boil Wort for 30 Minutes
- 7) Follow Hop Addition Schedule
- 8) Chill Wort
- 9) Filter Trub
- 10) Pitch Yeast
- 11) Measure original gravity
- 12) Ferment Wort at 65°F
- 13) Auto siphon & Bottle Style
- 14) Add Variant Ingredients
- 15) Ferment Variant
- 16) Final Bottling



We keep portions of our spent grains for cooking, and the rest of our spent grains are composted. See Sustainability section for more details.



Balance

Water: Mash (2 gallons) + Grain rinse (1.5 gallon) = Final Bottling (2.8 gallons) → loss to evaporation, grains, yeast (0.7 gallons)

Grains: Mash (5.65 lbs.) = Extract (1.6 lbs.), Bread (1.5 lbs.), Compost (2.55 lbs.)

Energy Water Nexus Estimated wort cooling load = 3 gal * 4.1 KJ/Kg *K (i.e. 0.89 BTU/lbm F) from 212F to maximum of 70F. Tap water at 65F is available at 1.56 gpm and would take ~ 20 minutes to cool wort (~ 31gal). The use of recycled rain water increases water of beer/utilized ratio from 0.08 (2.8/ 2.8 +0.7 +31) to 0.8 (2.8/3.5)!

Review of Our Experience

Our focus has been to develop repeatable nano brewing techniques while also relating the art of brewing to rigorous science and engineering. As we develop quality recipes we continue to change our practice to make as sustainable and efficient as possible. Style recipes we have developed include a 'bock', brown, and we are refining an approach to new England IPA with strong fruity aroma and a smooth creamy mouth feel.

Our FES is a tropical style with a moderate attenuating yeast strain and high end OG. We also minimize hop additions for minimal bitterness or aromas associated with hops.

Our variant utilized a secondary fermentation with additions that increase ABV by an estimated 1%, also introducing a spicy sweet flavor that we propose as celebration of the beginning of the traditional time frame that FES were traditional brewed, i.e. October to April.

SUSTAINABILITY

As active members of AIChE's Sustainable Engineering Forum (SEF), we also incorporated some sustainable practices into our beer making process.

1) **Source of Ingredients** – Ingredients were chosen with location in mind to reduce impact of transportation.

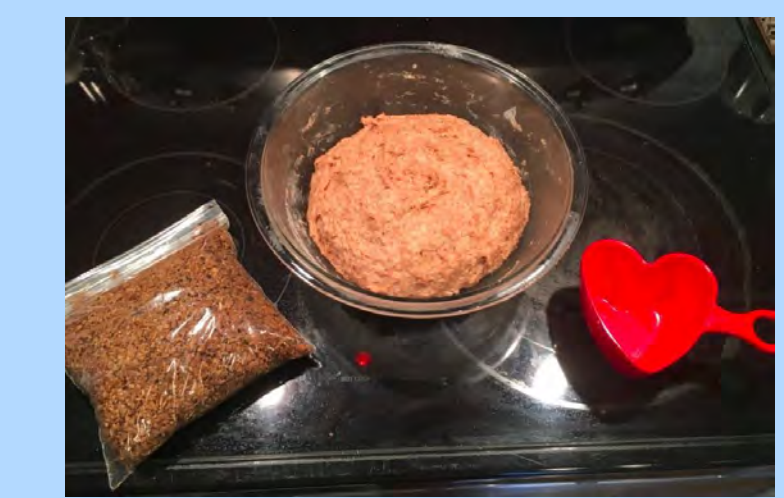
Grains – 98% of the grains used were sourced from the USA (Briess – Chilton, WI)

Yeast – Although the most widely used yeast providers are White Labs (Asheville, NC) and Wyeast (Hood River, OR), we chose RVA Yeast Labs [5] because they are based in Richmond, VA.

2) **Cooling Water Source and Re-use** – Rain barrel water was supplied via manual siphon pump to the immersion wort chiller. Water was returned to the rain barrel and reused in subsequent brewing processes.



3) **Re-use and Composting of Spent Grains** – From each batch of beer, 3 cups of spent grains were used to make a loaf of bread.

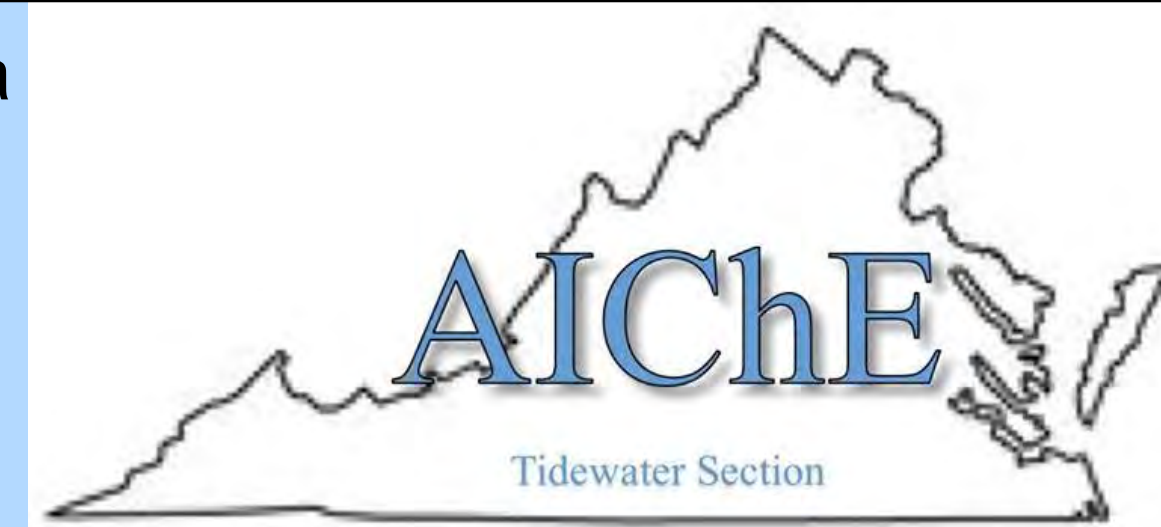


The remaining grains were added to our compost pile, which generates soil for our vegetable garden.



ACKNOWLEDGEMENTS

We thank the Tidewater Virginia AIChE local section for their support of our participation in the in the first AIChE beer competition.



REFERENCES

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5. RVA Yeast Labs <http://www.rvayeastlabs.com/>