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#ElevateBeer

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

Kurt Driesner[1,2], Val Peacock[3], Florian Kuplent[2], and Amanda Mikolay[2]

How half a century of evolution in the brewing industry has affected the relevance of the IBU

1. Presenter
2. Urban Chestnut Brewing Company
3. Hop Solutions Inc.

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

The purpose of this exploratory study was to test the usefulness and validity of the IBU in quantifying subjective bitterness:

- Is pH a significant factor in perceived bitterness?
- Do dry-hopping constituents influence perceived bitterness?
- What role, if any, does ABV have in influencing perceived bitterness?
- Does the IBU accurately estimate the quality of perceived bitterness?

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

A trained sensory panel was used to explore the dynamics of perceived bitterness in modern craft brewing:

- A consensus scale for ‘mouth’ (initial) and ‘linger’ (duration) was generated using calibration standards ‘spiked’ with isomerized-alpha-acid extract

- Examined
  - pH
  - ABV
  - Non-isomerized alpha acid (AA) addition
  - CO_2 extracted hopping (spent-hopping)
  - Dry-hopping

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

Panel Calibration:

- Nine panelists were trained
  - Focused on bitterness (taste buds)
  - Ignored secondary mouth sensations (e.g., astringency, ethanol ‘heat’)
  - Consensus scoring was focused on IBU scores ranging from 25 to 65
  - Scale was 0 – 10 with half points permitted
- The same sensory calibration standards were used as reference throughout the duration of the study
- All panel scores presented as means

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

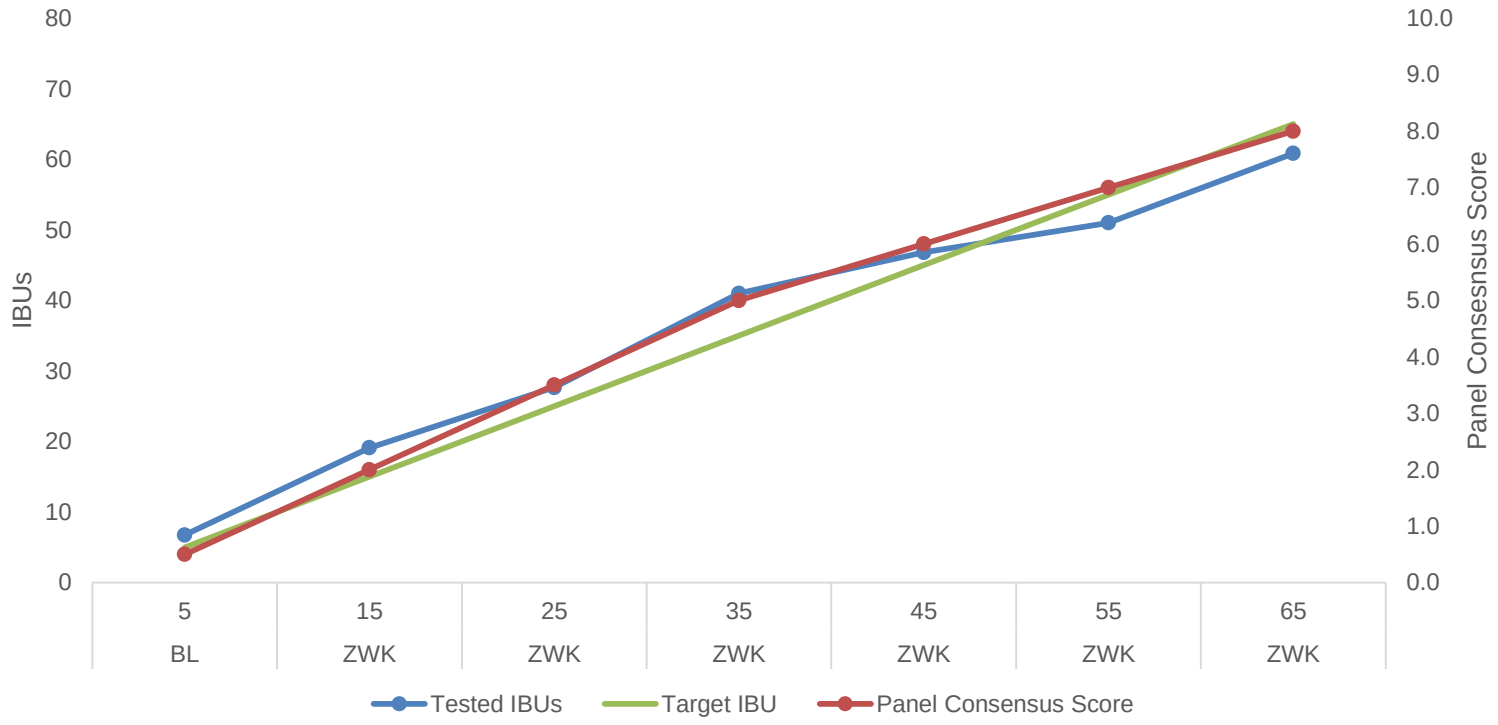


Fig. 1: Tested IBU vs Target IBU (ASBC International Method) With Panel Consensus Score

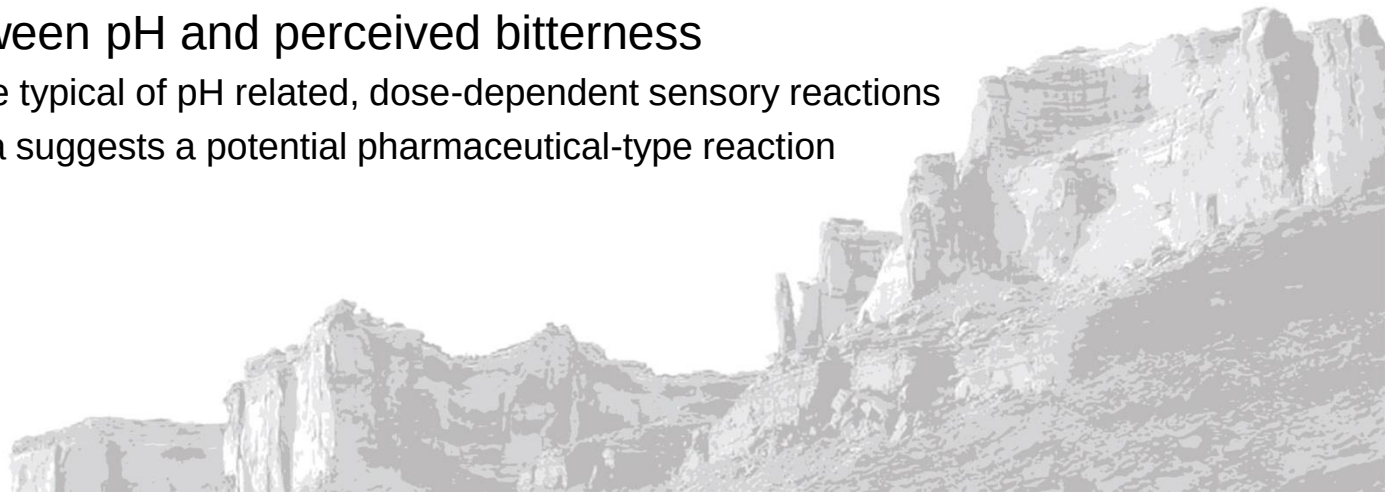
The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

The effect of pH on perceived bitterness:

- pH is a very important variable in all aspects of brewing
  - It has been long postulated that pH could be a major factor in determining ‘fine’ vs ‘coarse’ bitterness [2]

- pH was manipulated using very small amounts of food grade phosphoric acid or food grade potassium hydroxide
  - Test beer pH varied from 4.1 to 4.9

- A theoretical model was created from the data to illustrate the non-linear relationship between pH and perceived bitterness
  - Non-linear curve typical of pH related, dose-dependent sensory reactions
  - Preliminary data suggests a potential pharmaceutical-type reaction to bitterness



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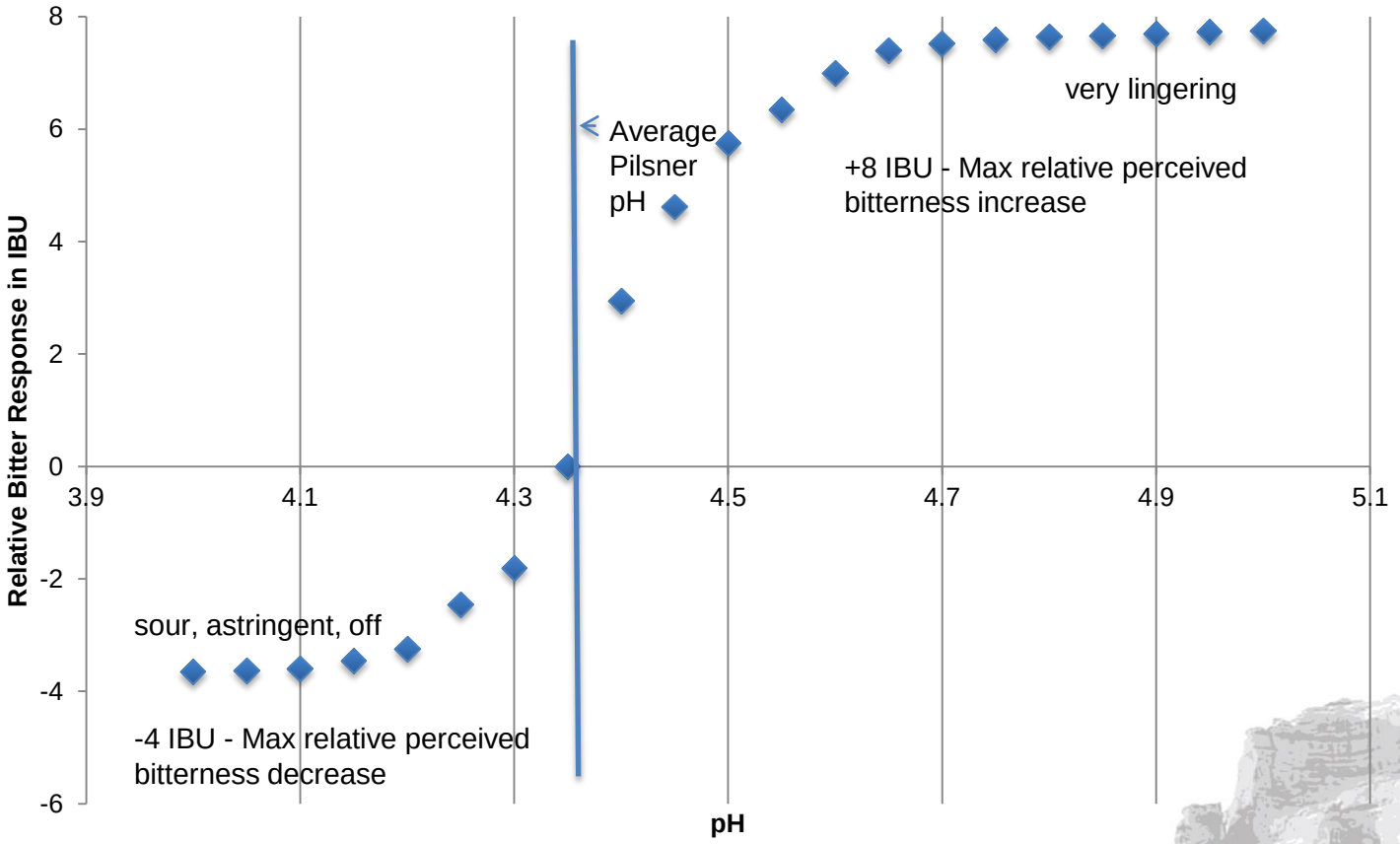


Fig 2: Theoretical pH model: Effect of pH on Perceived IBUs (45 IBU Beer)

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

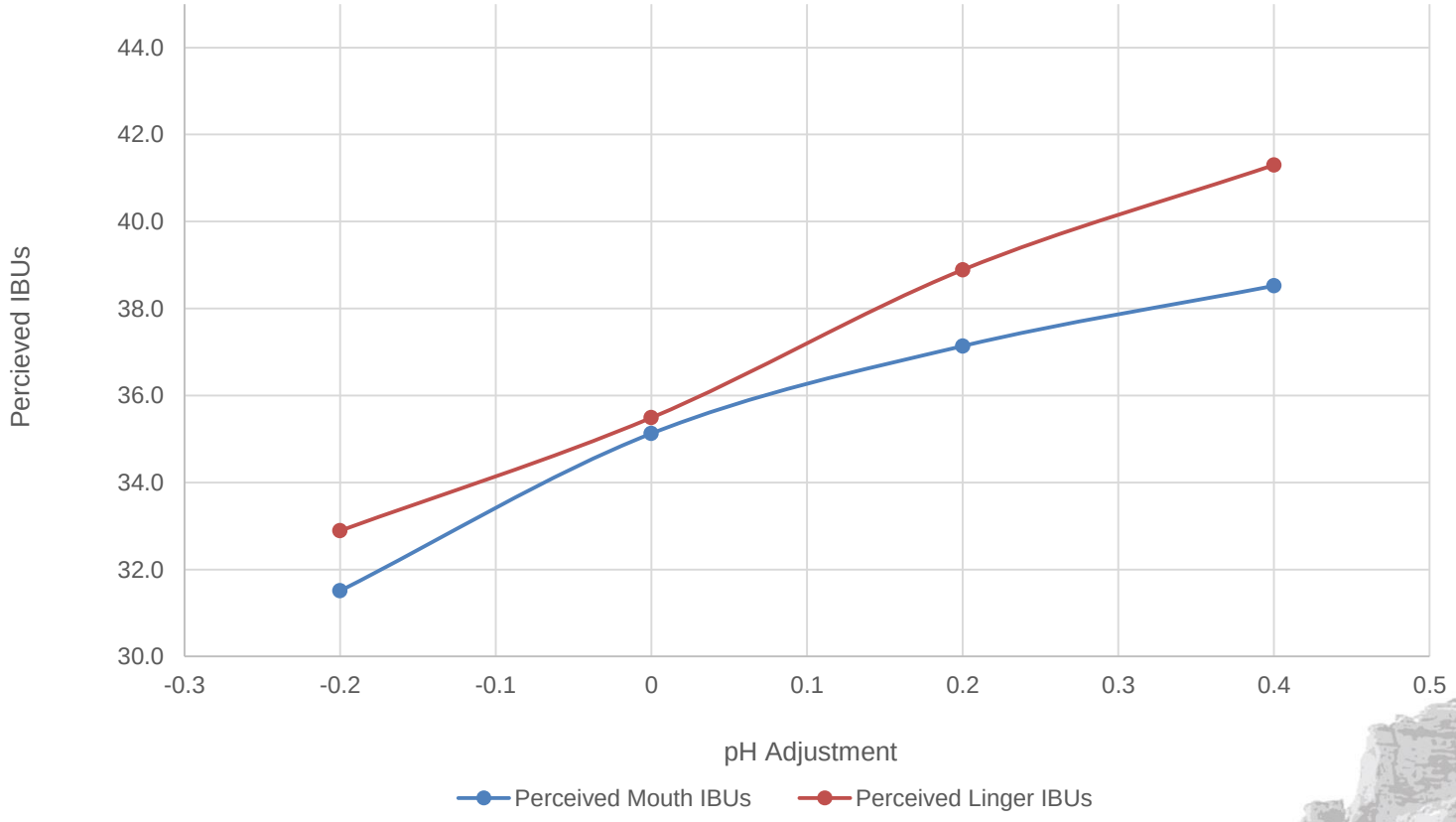
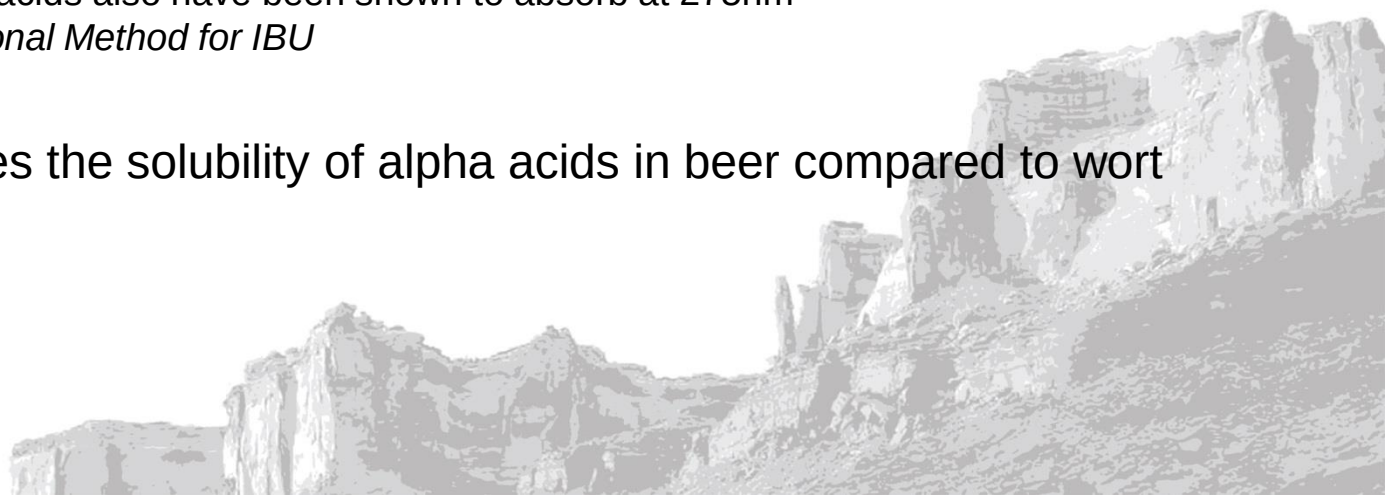


Fig 3: Observed Data: Effect of pH on Perceived IBUs (Pilsner)

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

The effect of non-isomerized alpha acids on perceived bitterness:

- A 7% (ABV) IPA was spiked with non-isomerized alpha acid extract immediately prior to sensory analysis
  - It has been postulated that non-oxidized, non-isomerized alpha acids do not contribute to perceived bitterness [1]
  - Oxidized alpha acids have been postulated to impact perceived bitterness to a lesser degree than isomerized alpha acids [6]
  - Oxidized-alpha acids also have been shown to absorb at 275nm
    ASBC International Method for IBU
- Ethanol increases the solubility of alpha acids in beer compared to wort



The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

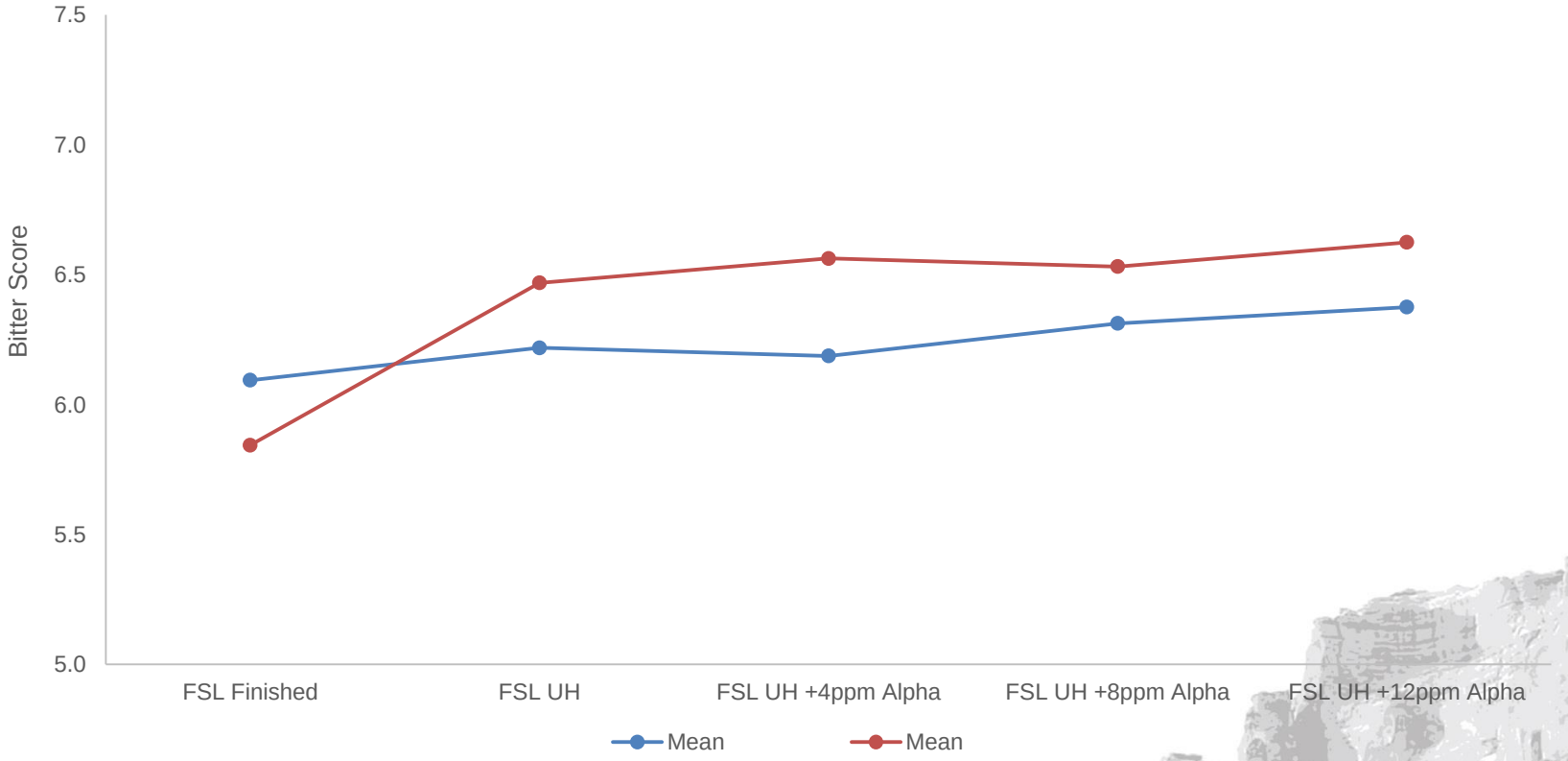


Fig 4: Mean Panel Scores for Alpha Acid Addition (IPA)

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

The effect of dry-hopping on perceived bitterness without the presence of alpha and beta acids:

- In a novel exercise, a base IPA was sequestered prior to production dry-hopping and instead dry-hopped with extracted hops (Millennium, HAAS)
    - ‘Spent’ hops have had their alpha and beta acids extracted with CO2 – leaving only the green matter and hop polyphenols behind
    - Un-dry-hopped base beer was tested against the three ‘spent’ hop treatments (1, 2, and 3 lbs./bbl.) and the finished production beer as a control
    - Trials were assessed with and without controlling for pH

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

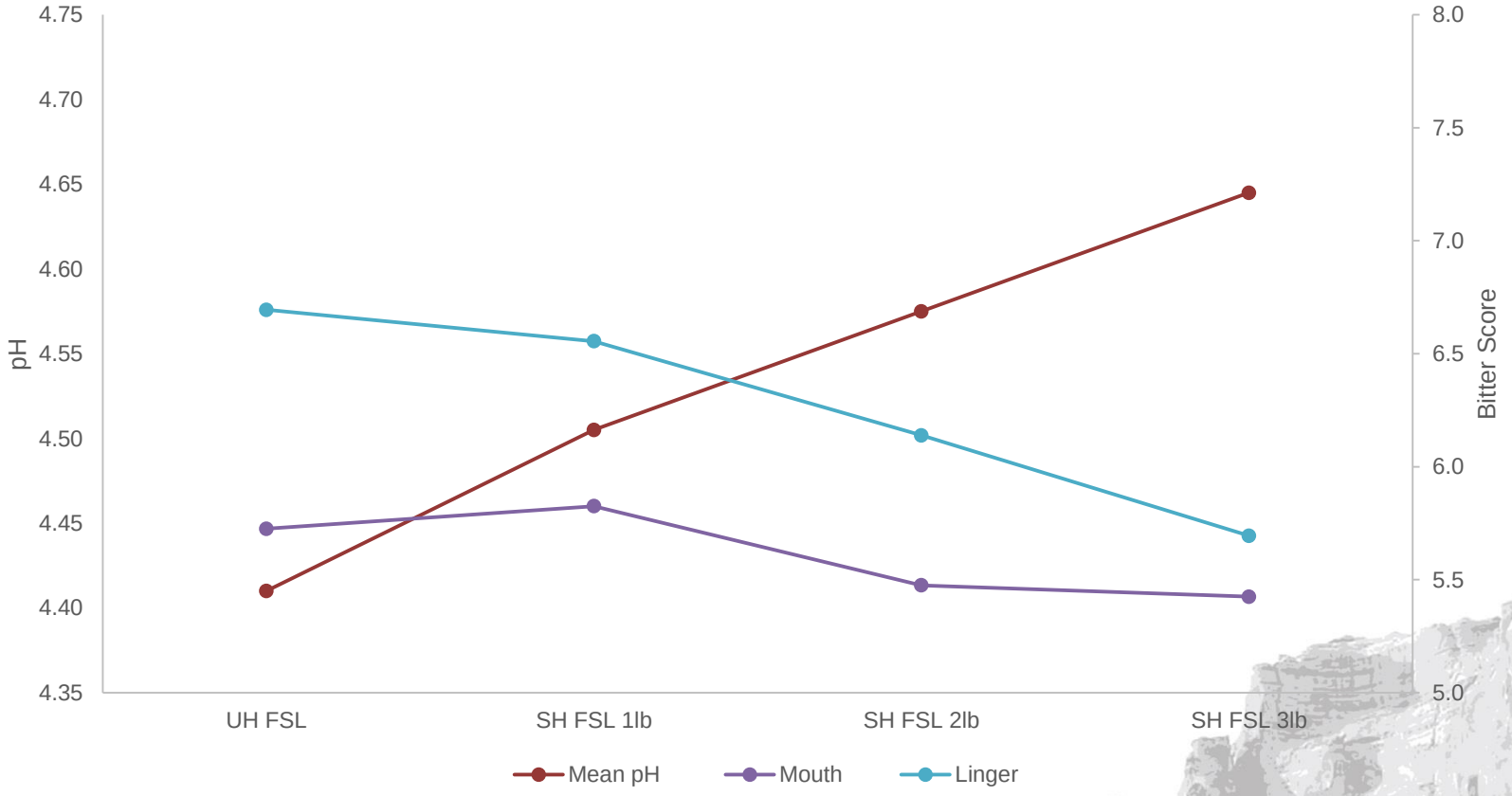


Fig 5: pH vs Panel Scores: Spent Hops (IPA, no pH adjustments)

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

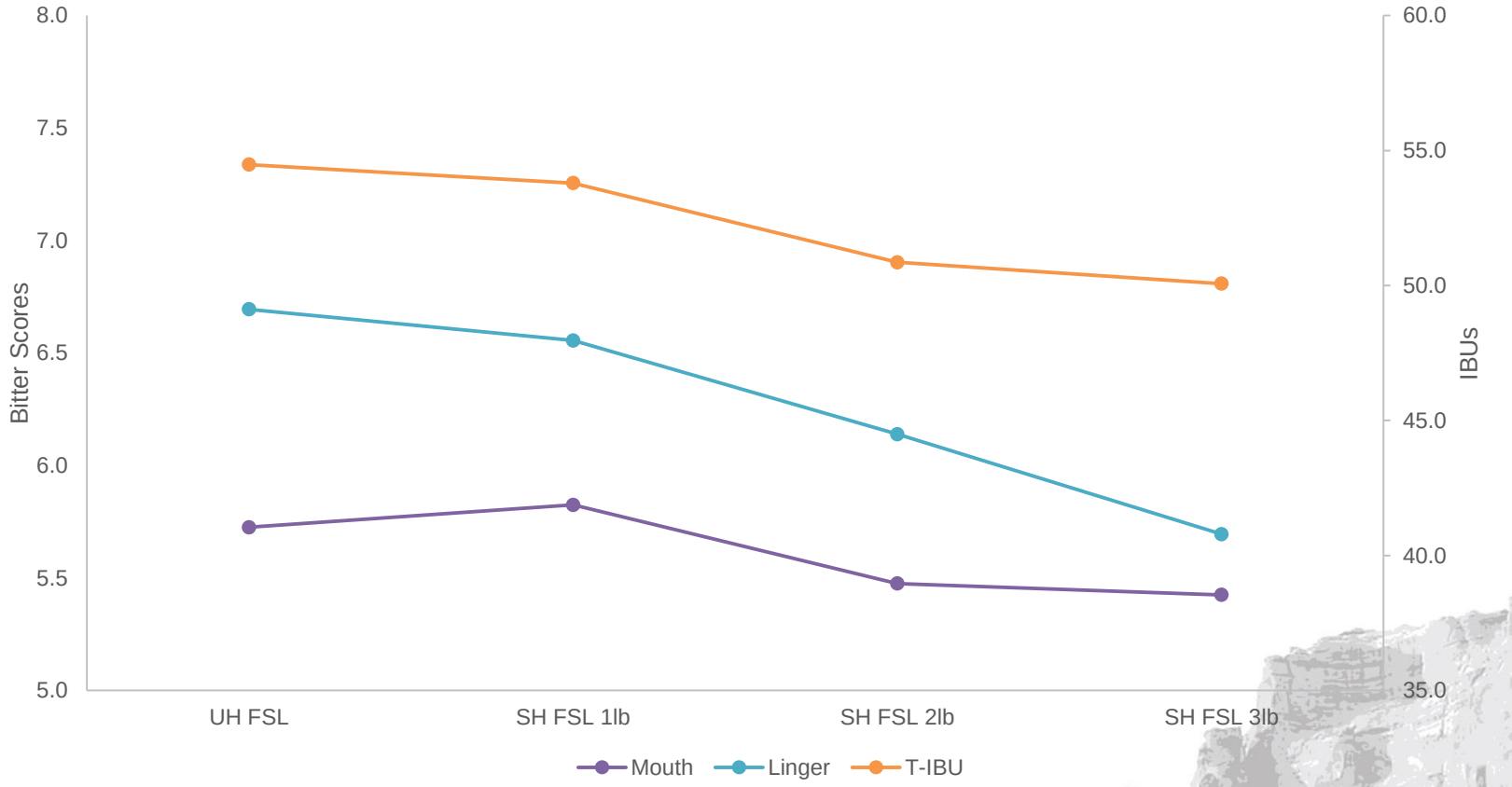


Fig 6: Panel Scores vs Measured IBUs: Spent Hops (IPA, no pH adjustments)

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

Effect of traditional dry-hopping on perceived bitterness:

- Based on our model for the effect of pH on bitterness, dry-hopping should increase perceived bitterness
  - Dry-hopping predictably raises the pH of finished beer 0.05 to 0.20 [6]

- Dry-hopping adds non-isomerized alpha acids to the finished beer [5, 6]
  - Non-isomerized alpha acids from dry-hopping may increase perceived bitterness (if oxidized) and should impact the rapid IBU test due to alpha acid oxidation during the liq-liq extraction

- Hop polyphenols, beta acids and the alkaline green matter complicate the finished matrix of the finished beer

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

Table 1: Perceived IBUs vs Predicted Perceived IBUs with Actual IBU Values

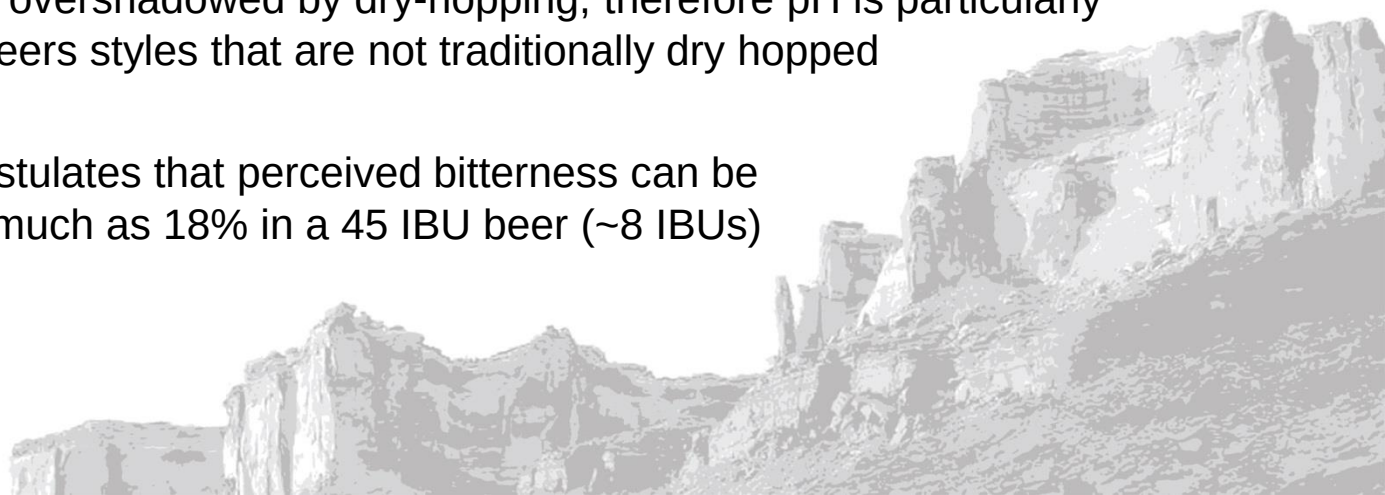
		Perceived IBUs		pH Model Predicted IBUs		ASBC Method
	Sample	Mouth IBU	Linger IBU	Mouth IBU	Linger IBU	Tested IBU
	UH IPA	41	48	*41*	*48*	**54**
	SH IPA 1lb	42	47	*42*	*50*	**54**
	SH IPA 2lb	39	44	*43*	*51*	**51**
	SH IPA 3lb	39	41	*43*	*53*	**50**
(7 days)	DH IPA 1.5lbs	**44**	**41**	*42*	*51*	**73**
(60 days)	DH IPA 1.5lbs	**41**	**47**	*42*	*51*	**73**

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

Conclusions:

pH is an important factor in perceived bitterness in the final product

- Greatest impact in perceived linger
- Can effect ‘coarse’ vs ‘fine’ bitterness possibly via ion dissociation or protein confirmation changes [2]
- Effect may be overshadowed by dry-hopping, therefore pH is particularly important in beers styles that are not traditionally dry hopped
- Our model postulates that perceived bitterness can be increased as much as 18% in a 45 IBU beer (~8 IBUs)

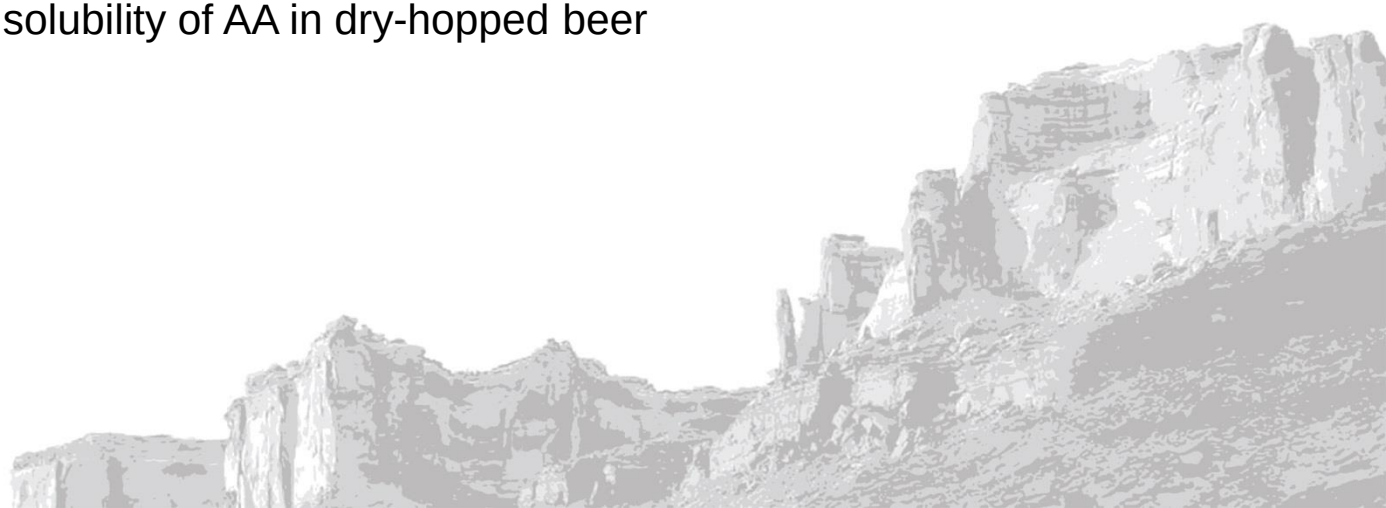


The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

Conclusions:

Non-Isomerized Alpha Acids do not contribute directly to perceived bitterness

- Oxidized AA may contribute to perceived bitterness after the fact [6]
- Addition of AA extract increased IBU results using International Method
- Ethanol does not appear to impact perceived bitterness directly but ABV increases the solubility of AA in dry-hopped beer

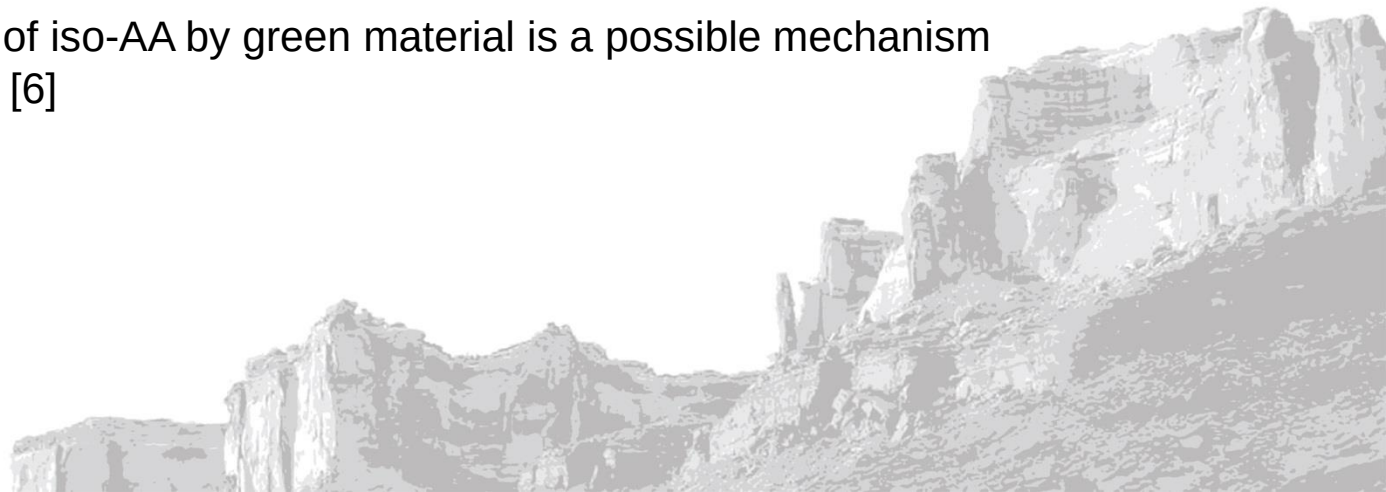


The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

Conclusions:

Dry hopping with extracted (spent) hop material reduced perceived bitterness, particularly the intensity and duration of bitter ‘linger’

- Inverse relationship between mass of spent hop material and perceived bitter linger
- Inverse relationship in relation to measured IBUs
- Reabsorption of iso-AA by green material is a possible mechanism to explain this [6]



The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

Conclusions:

Dry hopping *reduced* perceived bitterness but *increased* the tested IBU value compared to the un-dry-hopped base beer

- Increase in IBU values may be due to added AA oxidation during the packaging process
- Initial panel results indicated decreased perceived IBUs, particularly decreased linger
- After 60 days, perceived IBUs were comparable to the un-hopped base IPA

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

Conclusions:

The current definition of the IBU is insufficient to accurately estimate perceived bitterness across the modern beer landscape

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

Conclusions:

Improvements to perceived bitterness assessment may include:

- Comprehensively modeling pH effects of finished beer styles
- Co-factor adjustments for ABV and Dry-Hop Mass (for dry-hopped styles)
- Adjustments for the effect of residual sugar (Real Extract)
- Oxidation modelling for packaged beer

The IBU, pH, Dry-hopping, ABV and Perceived Bitterness

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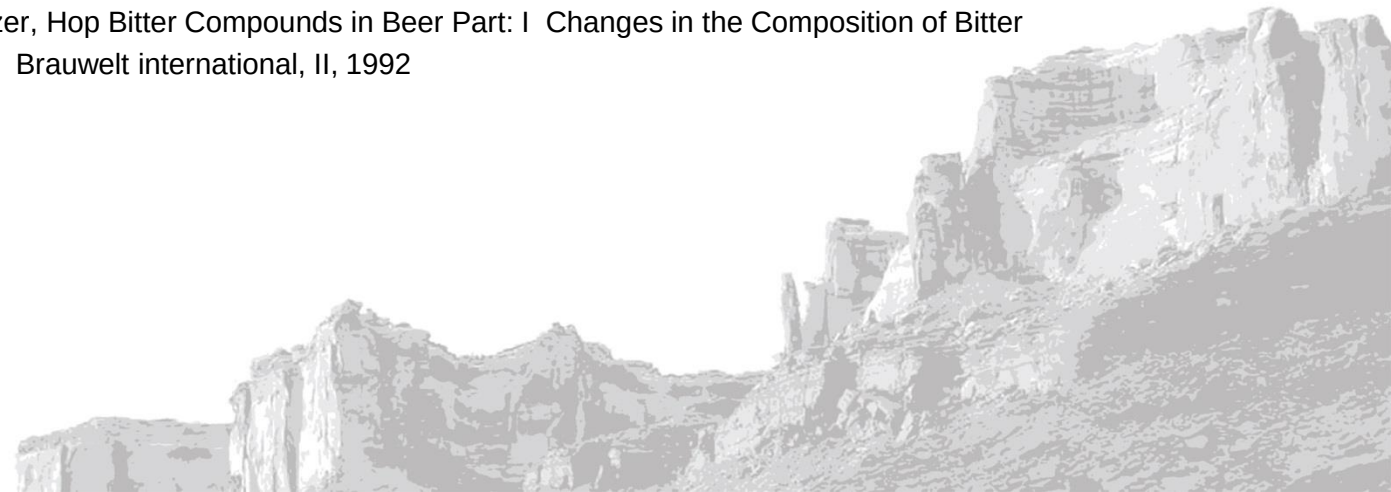

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Questions?

(Five minute discussion)

Special thanks to HAAS for providing Hop Products for this study!