ASBC Annual Meeting

June 4–7 ■ Fort Myers, Florida U.S.A.

PROGRAM

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Welcome from the Program Chair

Follow us on Twitter at #ASBC2017

Hello! As ASBC Program Chair, I am happy to welcome you to the 2017 ASBC Annual Meeting in sunny Fort Myers, Florida! We've lined up a program full of engaging presentations, interactive workshops, and cutting-edge science.

The meeting kicks off with Keynote Speaker Barbara Dunn of Stanford University talking about "What's Brewing in Yeast Genetics?" After that, we have more than three days of top-notch technical sessions, workshops, and special sessions.

Our program features 70 technical presentations in oral sessions and posters, with topics spanning from Stability to Microbiology to Omics, and more. Make sure to stop by the posters to take a look at what's happening in brewing science.

On Tuesday, we are honored to have Kevin Verstrepen present, "Studying the Yeasts of Yesterday to Generate the Beer Yeasts of Tomorrow." Other must-attend sessions include Beer Abby, where you can get your questions answered by your peers; "Beer Time Tales," where industry experts Charlie Bamforth and Patrick Ting will share experiences from their careers; and the "Innovative Methods" session, where you can participate in the *ASBC Methods of Analysis* process.

Then, I hope you brought your Hawaiian shirt, because surf's up at the Suds & Sand Beach Party on Tuesday night. We'll all be hanging loose with some tasty munchies and, of course, great beer! I'll see you there!

Finally, we close out the meeting with a dash of networking at the Beer-lympics! Engage in friendly competition while building connections that will last to the next meeting. We've been working hard to make sure this event is a fun, memorable way to wrap up the meeting!

We couldn't have done all this without you, attendees. I look forward to meeting you throughout the meeting.

Dan Vollmer
ASBC Annual Meeting Program Chair

Annual Meeting Program Committee

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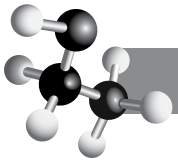

Schedule-at-a-Glance

Friday, June 2		
8:00 a.m.–5:00 p.m.	Pre-Meeting Course: **Building a Sensory Program for your Brewery** (Day 1)	*Caloosa B*
Saturday, June 3		
8:00 a.m.–5:00 p.m.	Board of Directors Meeting	*Jasmine*
8:00 a.m.–5:00 p.m.	Pre-Meeting Course: **Building a Sensory Program for your Brewery** (Day 2)	*Caloosa B*
2:00–6:00 p.m.	Registration Open	*Palms Foyer*
7:00–7:30 p.m.	**First-Timers Mixer**	*Banyan*
7:30–9:00 p.m.	**Brains & Beer Trivia Night**	*Gardens Ballroom*
Sunday, June 4		
7:30 a.m.–6:00 p.m.	Registration Open	*Palms Foyer*
7:00–8:00 a.m.	Speaker Breakfast	*Gardens Ballroom*
8:00–10:00 a.m.	Opening Session and Keynote: **What's Brewing in Yeast Genetics?**	*Everglades Ballroom*
10:15–11:30 a.m.	Technical Session 1: **Omics**	*Caloosa Ballroom*
10:15 a.m.–12:00 p.m.	Workshop: **Cross-Brewing Quality Assurance**	*Everglades Ballroom*
1:30–2:30 p.m.	**Innovative Methods Session**	*Everglades Ballroom*
2:45–4:00 p.m.	Technical Session 2: **Hops I**	*Gardens Ballroom*
2:45–4:00 p.m.	Workshop: **Back to Basics: How to Set Up a Brewing Quality Lab**	*Everglades Ballroom*
2:45–4:00 p.m.	Workshop: **Craft Distilling I - Technical Discussion**	*Caloosa Ballroom*
4:00–6:00 p.m.	**Exhibit and Poster Opening Happy Hour**	*Palms Ballroom*
Monday, June 5		
8:00 a.m.–5:00 p.m.	Registration Open	*Palms Foyer*
8:30–10:15 a.m.	Technical Session 3: **Analytical Flavors**	*Caloosa Ballroom*
8:30–10:15 a.m.	Workshop: **New Frontiers in Microbiology**	*Everglades Ballroom*
10:30 a.m.–12:30 p.m.	Workshop: **The U.S. Malt Scene**: **Hot Topics and Hip Approaches**	*Everglades Ballroom*
12:30–2:30 p.m.	Exhibits, Posters, and Lunch	*Palms Ballroom*
2:30–3:20 p.m.	Special Session: **Beer Time Tales**	*Everglades Ballroom*
3:30–4:45 p.m.	Technical Session 4: **Yeast**	*Camellia AB*
3:30–4:45 p.m.	Workshop: **Craft Distilling II - Tasting**	*Caloosa Ballroom*
3:30–4:45 p.m.	Workshop: **Hops I - Sensory Evaluation of Hops**	*Everglades Ballroom*

Tuesday, June 6		
8:00 a.m.–5:00 p.m.	Registration Open	*Palms Foyer*
8:30–9:45 a.m.	Technical Session 5: **Stability**	*Camellia AB*
8:30–10:15 a.m.	Workshop: **Hops II - Interfacing with the Hop Industry**	*Everglades Ballroom*
8:30–10:30 a.m.	Workshop: **Technical Barrel Aging**	*Caloosa Ballroom*
10:30–11:30 a.m.	Guest Speaker: **Studying the Yeasts of Yesterday to Generate the Beer Yeasts of Tomorrow**	*Everglades Ballroom*
11:30 a.m.–1:30 p.m.	Exhibits, Posters, and Lunch	*Palms Ballroom*
1:45–3:30 p.m.	Workshop: **Application of Chromatography to Brewing Analysis**	*Camellia AB*
1:45–3:30 p.m.	Workshop: **Building a Research Program for Craft Breweries**	*Caloosa Ballroom*
1:45–3:30 p.m.	Technical Session 6: **Sensory**	*Everglades Ballroom*
3:45–4:30 p.m.	Special Session: **Beer Abby**	*Everglades Ballroom*
7:00–9:30 p.m.	**Suds & Sand Beach Party**	*Everglades Pool Deck and The Cove Beach Area*
Wednesday, June 7		
7:45–10:30 a.m.	Registration Open	*Palms Foyer*
8:15–10:00 a.m.	Technical Session 7: **In-Process QA**	*Everglades A*
8:15–10:00 a.m.	Technical Session 8: **Microbiology**	*Harbourview (1st Floor)*
9:00–11:00 a.m.	Workshop: **Executing and Understanding Sensory Thresholds in Beer**	*Caloosa Ballroom*
10:15–11:30 a.m.	Technical Session 9: **Hops II**	*Harbourview (1st Floor)*
11:30 a.m.–1:00 p.m.	**Beer-lympics**	*Everglades Ballroom*

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Edited by: Nicholas A. Bokulich and Charles W. Bamforth
vi + 332 pages, June 2017
Book: ISBN 978-1-910190-61-6, £159 / US$319
Ebook: ISBN 978-1-910190-62-3, £159 / US$319

This volume surveys the most recent discoveries in brewing microbiology, with an emphasis on omics techniques and other modern technologies. Discoveries in these areas have furthered our knowledge of brewing processes, with practical applications from barley growth and malting to yeast management, strain selection, fermentation control, and quality assurance. The chapters, written by experts in the field, aim not only to illuminate recent progress, but also to discuss its impact on brewing practices. Topics covered include the physiology, fermentation, taxonomy, diversity, typing, genetic manipulation, genomics and evolution of brewing yeasts. Further areas covered include the fungal contamination of barley and malt, spoilage by lactic acid bacteria and gram-negative bacteria, and beer-spoiling yeasts. This volume is highly recommended for anyone involved in the microbiology of brewing.

Topics

• Brewing Yeast Physiology. • Yeast Stress and Brewing Fermentations. • Yeast Supply, Fermentation, and Handling Insights, Best Practice and Consequences of Failure. • Taxonomy, Diversity, and Typing of Brewing Yeasts. • Genetic Manipulation of Brewing Yeasts: Challenges and Opportunities. • Genomics and Evolution of Beer Yeasts. • Microbial Ecology of Traditional Beer Fermentations. • Fungal Contamination of Barley and Malt. • Investigation of Beer-Spoilage Lactic Acid Bacteria using Omic Approaches. • Brewery- and Beer-Spoilage-Related Gram-negative Bacteria: The Unpleasant, The Malodorous and The Outright Fetid. • Beer-Spoiling Yeasts: Genomics, Detection, and Control.

Further details at: www.caister.com/brewing

TECHNIQUES

- **MALDI-TOF Mass Spectrometry in Microbiology**
Edited by: M Kostrzewa, S Schubert
x + 170 pages, **June 2016**,
Book: 978-1-910190-41-8, £159 / US$319
Ebook: 978-1-910190-42-5, £159 / US$319
Overview of MALDI-TOF MS in key areas of microbiology and the impact of mass spectrometry in diagnostics, food microbiology, environmental microbiology and strain collections.

- **Gas Plasma Sterilization in Microbiology: Theory, Applications, Pitfalls and New Perspectives**
Edited by: H Shintani, A Sakudo
viii + 158 pages, **January 2016**,
Book: 978-1-910190-25-8, £129 / US$259
Ebook: 978-1-910190-26-5, £129 / US$259
"a nice state of the art compilation" **Doodys**;

- **Flow Cytometry in Microbiology: Technology and Applications**
Edited by: MG Wilkinson
xii + 218 pages, **September 2015**,
Book: 978-1-910190-11-1, £159 / US$319
Ebook: 978-1-910190-12-8, £159 / US$319
"an impressive group of experts" **ProtoView**; *"practical and up-to-date information"* **Biotechnol. Agron. Soc. Environ.**; *"a variety of valuable information"* **Biospektrum**

- **Microbial Biodegradation: From Omics to Function and Application**
Edited by: J Długoński
x + 238 pages, **September 2016**,
Book: 978-1-910190-45-6, £159 / US$319
Ebook: 978-1-910190-46-3, £159 / US$319
Essential Reading!

- **Aquatic Biofilms: Ecology, Water Quality and Wastewater Treatment**
Edited by: AM Romaní, H Guasch, MD Balaguer
xii + 230 pages, **January 2016**,
"essential reference book" **Biotechnol. Agron. Soc. Environ.**

- **Probiotics and Prebiotics: Current Research and Future Trends**
Edited by: K Venema, AP Carmo
xvi + 508 pages, **August 2015**,
Book: 978-1-910190-09-8, £219 / US$360
Ebook: 978-1-910190-10-4, £219 / US$360
The 33 chapters of this book serve as an invaluable resource for everyone working with probiotics, prebiotics and the gut microbiotflora.

General Information

Registration Hours
Location: Palms Foyer

Saturday, June 3 ..... 2:00–6:00 p.m.
Sunday, June 4 ..... 7:30 a.m.–6:00 p.m.
Monday, June 5 ..... 8:00 a.m.–5:00 p.m.
Tuesday, June 6 ..... 8:00 a.m.–5:00 p.m.
Wednesday, June 7 ..... 7:45–10:30 a.m.

Please wear your name badge at all times to ensure access to sessions and events. Event tickets must be presented at their applicable events.

Hospitality Room Hours
Location: Island Room

Saturday, June 3 ..... 2:00–11:00 p.m.
Sunday, June 4 ..... 6:00–11:00 p.m.
Monday, June 5 ..... 4:45–11:00 p.m.
Tuesday, June 6 ..... 4:30–7:00 p.m., 9:30–11:30 p.m.

Quilt Raffle
Take a chance to win one of three quilts sewn out of beer-related logos, and support students by doing so! Proceeds go toward supporting ASBC students in brewing education. The raffle will end on Tuesday, June 6, at 1:40 p.m., with winners announced during the Beer Abby session at 3:45 p.m. Tickets are available at the registration desk for $5 each, or 5 for $20. You don't need to be present to win, but the first and second winners selected and present will have priority selection on quilts. A special thanks to Mary Giarratano for making the quilts.

Charging Station
Stop by the charging station to give a boost to your phone or mobile device. The Charging Station is located in the Palms

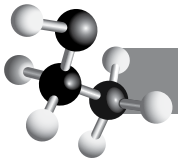
The Charging Station is sponsored by GEA Group.

Guests
Guests wishing to attend the Suds & Sand Beach Party must purchase a ticket to attend. Guests do not have access to technical sessions, workshops, or the exhibit hall, and they must register and have a name badge to gain access to the hospitality room. Coworkers and business associates are not considered guests and must pay the appropriate registration fees.

Technical Subcommittees
The technical subcommittees will meet during the Innovative Methods session on Sunday. Attend the session to help ensure the ongoing quality of the *ASBC Methods of Analysis*. Discussion is specific to a technical subcommittee run from 2016–2017 and will provide an overview of the committee's results and recommendations. The discussions are open to all, and your feedback and participation are essential to the methods program.

Speaker Kiosk
The speaker kiosk will be available for speakers to review their presentations the day before their scheduled session. The kiosk is located in the Palms Foyer near registration and is open during registration hours.

Photo Release
Photographs will be taken at the 2017 ASBC Annual Meeting for use in promotional materials after the meeting has concluded. By registering for this meeting, you agree to allow ASBC to use your photo.



Program

Friday, June 2

8:00 a.m.–5:00 p.m.	Technical Committee Meeting	*Jasmine*
8:00 a.m.–5:00 p.m.	Pre-Meeting Course: **Building a Sensory Program for your Brewery** (Day 1)	*Caloosa B*

Saturday, June 3

8:00 a.m.–5:00 p.m.	Board of Directors Meeting	*Jasmine*
8:00 a.m.–5:00 p.m.	Pre-Meeting Course: **Building a Sensory Program for your Brewery** (Day 2)	*Caloosa B*
2:00–6:00 p.m.	Registration Open	*Palms Foyer*
2:00–11:00 p.m.	Hospitality Room Open	*Island Room*
7:00–7:30 p.m.	**First-Timers Mixer**	*Banyan*
7:30–9:00 p.m.	**Brains & Beer Trivia Night**	*Gardens Ballroom*

Friday and Saturday Highlights

Pre-Meeting Course: Building a Sensory Program for your Brewery

Friday, June 2, 8:00 a.m.–5:00 p.m.; Saturday, June 3, 8:00 a.m.–5:00 p.m. • Caloosa B

Patricia Aron, Rahr Malting Co.; Lindsay Barr, New Belgium Brewing Co.; Mary-Jane Maurice, Malteurop North America Inc.; Christina Schoenberger, Joh. Barth & Sohn GmbH & Co. KG; Suzanne Thompson, MillerCoors; Sylvie Van Zandycke, Lallemand

This two-day course brings in experts representing raw materials and quality programs from across the brewing industry. Follow the path of ingredients through the brewing process to finished beer and learn how sensory science is applied with a focus on appropriate sensory evaluation methods at each step. Your instructors will provide up-to-date and effective methods of sensory evaluation, from assessing off-flavors to deciphering bitterness as an element of taste. Whether you are vetting a new ingredient or process in your brewery or directing product development, this course provides the tools for executing a sound sensory program.

First-Timers Mixer

7:00–7:30 p.m. • Banyan

Are you a first-time attendee, student, or returning attendee looking to meet new people? Then this event is for you! Join us for tips and suggestions on how to make the most of your meeting experience. Mix and mingle while you enjoy a pint on us, then head off to Trivia Night.

Brains & Beer Trivia Night

7:30 –9:00 p.m. • Gardens Ballroom

You bring the brains; we'll bring the beer! Fire up your synapses and dominate the competition at the Saturday night pre-meeting trivia bash! This after-dinner activity is a perfect way to network prior to the meeting kick-off on Sunday morning. Make connections, lounge around, and blow your own horn—sing your own praises—and lay it on thick how much better your team truly is. In this spirited game of twisted trivia, may the beer be ever in your favor.

Sunday, June 4

7:30 a.m.–6:00 p.m.	Registration Open	*Palms Foyer*
7:00–8:00 a.m.	Speaker Breakfast	*Gardens Ballroom*
8:00–10:00 a.m.	Opening Session and Keynote: **What's Brewing in Yeast Genetics?**	*Everglades Ballroom*
10:15–11:30 a.m.	Technical Session 1: **Omics**	*Caloosa Ballroom*
	Moderator: Scott Britton, Duvel Moortgat, NV	
	10:15 a.m. 1. L. Chadwick. MetabAromics: A semi-targeted approach to beer analysis	
	10:40 a.m. 2. N. Rettberg. Bridging significant gaps? Application of a metabolomics platform in beer quality control	
	11:05 a.m. 3. J. Young. Mapping the microbiome of malted barley (from varied regions, varietals, and harvest years) and wort soured using the barley	
10:15 a.m.–12:00 p.m.	Workshop: **Cross-Brewing Quality Assurance**	*Everglades Ballroom*
11:00 a.m.–3:00 p.m.	Exhibit and Poster Set-up	*Palms Ballroom*
1:30–2:30 p.m.	**Innovative Methods Session**	*Everglades Ballroom*
2:45–4:00 p.m.	Technical Session 2: **Hops I**	*Gardens Ballroom*
	Moderator: Daniel Vollmer, Anheuser-Busch Inbev	
	2:45 p.m. 31. T. Shellhammer. Sensory directed mixture study of beers dry-hopped with Cascade, Centennial, and Chinook	
	3:10 p.m. 5. K. Reglitz. The black currant-like smelling aroma compound 4MMP—Influence of variety, provenance, and processing on the concentration in hops	
	3:35 p.m. 6. M. Uemoto. Effect of hop harvest date on the thiol contents in hop cone	
2:45–4:00 p.m.	Workshop: **Back to Basics: How to Set Up a Brewing Quality Lab**	*Everglades Ballroom*
2:45–4:00 p.m.	Workshop: **Craft Distilling I - Technical Discussion**	*Caloosa Ballroom*
4:00–6:00 p.m.	**Exhibit and Poster Opening Happy Hour**	*Palms Ballroom*
	4:30–5:30 p.m. All poster authors at poster	
6:00–11:00 p.m.	Hospitality Room Open	*Island Room*

Sunday Highlights

Opening Session and Keynote: What's Brewing in Yeast Genetics?

8:00–10:00 a.m. • Everglades Ballroom

Barbara Dunn,
Stanford University Medical School

Brewing yeasts are notoriously difficult to work with genetically, due to their complex genomes which are often polyploid, aneuploid, and/or derived from interspecific hybridization events. However, new techniques, as well as the repurposing of more traditional techniques, hold promise for genetic manipulations of brewing yeasts as a way to combine or enhance beneficial traits already present in such yeasts, or to possibly identify and introduce novel traits from non-brewing yeasts. Some of these new or repurposed techniques can result in non-genetically-modified (non-GM) yeasts, but other "minimally invasive" GM techniques now exist that may eventually be deemed acceptable by consumers and the brewing industry as a way to obtain brewing yeasts with desired traits. Overall, a wide variety of tools are now available for the genetic manipulation of brewing yeasts to alter or enhance any of a number of characteristics, from fermentation behavior to sensory profile.

Barbara Dunn is a senior research scientist in the Department of Genetics at Stanford University, currently working in the laboratories of Mike Snyder and Gavin Sherlock. She received her A.B. degree in botany at U.C. Berkeley, and her Ph.D. in biological chemistry at Harvard University, where she studied yeast telomeres in the laboratory of Jack Szostak. Her recent research has focused on using whole-genome DNA and RNA sequencing, ChIP-Seq, array-CGH, and other "omics" methods to broadly explore evolution in yeast, and particularly the genome structures and genome evolution of industrial yeasts (e.g., lager, ale, wine, ethanol, and bread).

Workshop: Cross-Brewing Quality Assurance

10:15 a.m.–12:00 p.m. • Everglades Ballroom

Mark Eurich, New Belgium Brewing Co.; Annette Fritsch, Boston Beer Co.; Jamie Wenham, Sierra Nevada Brewing Co.; Lauren Zeidler, Ballast Point Brewing and Spirits

As the brewing industry grows, maintaining beer quality and consistency across multiple brewing locations is a growing challenge for many brewers, small and large. This interactive course will highlight quality programs directed at achieving this goal. We will address all avenues of quality, including sensory and flavor matching, quality measurements throughout the brewing process, and water quality. This workshop should leave you with the fundamental tools needed to maintain quality across multiple brewing locations. There will be ample time at the end to ask questions of both the panel of speakers as well as other workshop attendees.

Innovative Methods Session

1:30–2:30 p.m. • Everglades Ballroom

Moderator: Mark Eurich, New Belgium Brewing Co.

The *ASBC Methods of Analysis* are a core part of what ASBC provides the brewing community, by assuring that brewing science is proven, vetted, tested, and peer reviewed. This session will allow attendees to join in the process by helping to grow the Methods. All you need is your experience to participate!

Workshop: Back to Basics: How to Set Up a Brewing Quality Lab

2:45–4:00 p.m. • Everglades Ballroom

Scott Britton, Duvel Moortgat, NV; Kimberly Hofecker, MillerCoors; Gina Shellhammer, GSJ Consulting

This workshop will explain how to set up a basic beer quality lab and develop a quality program. Discussions will cover how to design a lab space, which instruments are key, glassware, utilities, and what to plan for in case of brewery or lab expansion to increase flexibility. Speakers will go over how to set up methods, validate methods according to *ASBC Methods of Analysis*, collect data, and do basic statistical and meaningful data interpretation.

Workshop: Craft Distilling I - Technical Discussion

2:45–4:00 p.m. • Caloosa Ballroom

Paul Hughes, Oregon State University; Elizabeth Rhoades, Diageo

Craft breweries are enjoying a period of explosive growth, and in the wake of such creative prosperity many are delving into the world of distilling. Though analogous to brewing, distilling can involve a specific set of regulatory, QA/QC, and process requirements. What are the hurdles involved with adding spirits to a brewery's portfolio, and how can a brewery environment be adapted to build and grow a distillery? Hear from industry experts as they share their experiences on such matters as quality assurance/control, barrel aging, and innovation.

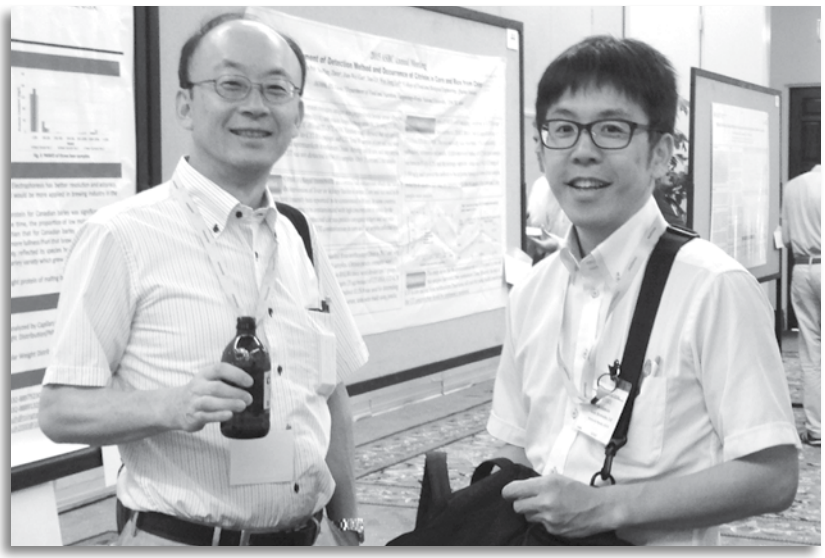
Exhibit and Poster Opening Happy Hour

4:00–6:00 p.m. • *Palms Ballroom*

Join us for Happy Hour to toast your first day at the meeting. This will be your opportunity to spend valuable time with industry suppliers and poster presenters to exchange ideas, expand your knowledge, and, most importantly, make rewarding connections. Enjoy beer and light snacks while you meet your fellow attendees and talk brewing science.

Monday, June 5

8:00 a.m.–5:00 p.m.	Registration Open	*Palms Foyer*
8:30–10:15 a.m.	Technical Session 3: **Analytical Flavors**	*Caloosa Ballroom*
	Moderator: Nils Rettberg, VLB Berlin	
	8:30 a.m. 7. T. Irie. Monitoring and control of onion-like off-flavor component precursor in large-scale brewing	
	8:55 a.m. 8. M. Segawa. New technologies for development of citrus-based ready-to-drink (RTD) alcoholic beverages that maintain freshness	
	9:20 a.m. 9. A. Shimmura. Influence of aging time on flavor and relevant compounds of barrel-aged beer	
	9:45 a.m. 10. K. Witrick. Comparison of the flavor and aroma compounds present in aging lambic beer	
8:30–10:15 a.m.	Workshop: **New Frontiers in Microbiology**	*Everglades Ballroom*
10:30 a.m.–12:30 p.m.	Workshop: **The U.S. Malt Scene: Hot Topics and Hip Approaches**	*Everglades Ballroom*
12:30–2:30 p.m.	Exhibits, Posters, and Lunch	*Palms Ballroom*
	1:00–1:30 p.m. Odd-numbered poster authors at poster	
	1:30–2:00 p.m. Even-numbered poster authors at poster	
1:00–2:00 p.m.	Charlie Bamforth Book Signing	*Palms Foyer*
2:30–3:20 p.m.	Special Session: **Beer Time Tales**	*Everglades Ballroom*
3:30–4:45 p.m.	Technical Session 4: **Yeast**	*Camellia AB*
	Moderator: Katherine Smart, SABMiller Plc	
	3:30 p.m. 11. P. Janssens. Shelf life and consistency of active dry yeast for breweries	
	3:55 p.m. 12. E. Moynihan. The relationship between brewery yeast handling and mitochondria development	
	4:20 p.m. 13. C. Powell. Variation within brewing yeast populations	
3:30–4:45 p.m.	Workshop: **Craft Distilling II - Tasting**	*Caloosa Ballroom*
3:30–4:45 p.m.	Workshop: **Hops I - Sensory Evaluation of Hops**	*Everglades Ballroom*
3:30–5:00 p.m.	Poster Viewing	*Palms Ballroom*
4:45–11:00 p.m.	Hospitality Room Open	*Island Room*



Monday Highlights

Workshop: New Frontiers in Microbiology

8:30–10:15 a.m. • Everglades Ballroom

Jessica Davis, The Bruery; Karen Fortmann, White Labs; Aimee Garlit, Dogfish Head Brewing Company; Elizabeth Nagle, Ballast Point Brewing

Microbiology for brewers has typically been about chasing spoilers, aseptic sampling, and various media for growth. Breweries are now using multiple flora for flavor development, aging on wood, providing fruit for secondary fermentation, creating mixed cultures, and allowing spontaneous fermentation. The new era creates opportunity for quality challenges and the long tale of a bug's life.

Workshop: The U.S. Malt Scene: Hot Topics and Hip Approaches

10:30 a.m.–12:30 p.m. • Everglades Ballroom

Cassie Liscomb, Briess Malt & Ingredients Co.; Chris Schooley, Troubadour Maltings; Chris Swersey, Brewers Association; Xiang Yin, Rahr Malting Co.

This workshop will cover the current state of the U.S. malting industry, featuring speakers embedded in the brewing and malting industries. The panel will address the growing divergence between adjunct and non-adjunct brewer needs in terms of malt quality parameters and overall usage. Hot topics to be discussed include malt innovation; emerging technical issues in barley growing and malting operations; progress in malt sensory analysis; and the state, struggles, and approaches of the craft malting industry.

Special Session: Beer Time Tales

2:30–3:20 p.m. • Everglades Ballroom

Charlie Bamforth, University of California; Patrick Ting, HopTing Resources

Join industry legends Charlie Bamforth and Patrick Ting as they share stories from their careers. Whether you're fresh to the field or your career's been aged in a fine oaken cask, you'll be sure to take away nuggets of wisdom from this light-hearted session.

Workshop: Craft Distilling II - Tasting

3:30–4:45 p.m. • Caloosa Ballroom

Christina Hahn, Oregon State University; Margaux Huismann, Heriot-Watt University; Amaey Mundkur, Cara Technology Limited

As a growing number of breweries seek to enter the world of craft distilling, it will become increasingly vital for the industry to understand the origins of flavor in their products. What parallels exist between beer and spirits flavor, and what are the critical differences? How do raw materials, processes, and aging affect the way we perceive spirits? Join us in an interactive session as we discover flavor contributions of spirits-specific raw materials, how various botanicals were foraged and analyzed to create a specific gin flavor profile, and how the aging process affects the sensory experience of bourbon.

This session requires a ticket purchase to attend.

Workshop: Hops I - Sensory Evaluation of Hops

3:30–4:45 p.m. • Everglades Ballroom

Victor Algazzali, John I. Haas, Inc.; Tiffany Pitra, Hopsteiner

As novel hop varieties reach the market and acreage expands, it is becoming increasingly important to evaluate raw materials for quality and consistency. Representatives from the industry will discuss topics such as hop sensory evaluation methods, implementation of sensory programs in the brewery, aroma evaluation throughout the hop selection process, and the application of sensory data. This interactive workshop will also allow attendees to participate in an interactive hands-on hop evaluation and data collection session—prepare to leave with lupulin covered hands!

Tuesday, June 6

8:00 a.m.–5:00 p.m.	Registration Open	*Palms Foyer*
8:30–9:45 a.m.	Technical Session 5: **Stability**	*Camellia AB*
	Moderator: Patricia Aron, Rahr Malting Co.	
	8:30 a.m. 14. J. Adler. Examination of indirect methods for the assessment of microbial stability in packaged beer	
	8:55 a.m. 16. T. Koyano. Influence of high temperature exposure during transportation on beer flavor	
	9:20 a.m. 17. B. Schottle. Detection of foam-negative lubricants on can lids by gas chromatography/mass spectrometry	
8:30–10:15 a.m.	Workshop: **Hops II - Interfacing with the Hop Industry**	*Everglades Ballroom*
8:30–10:30 a.m.	Workshop: **Technical Barrel Aging**	*Caloosa Ballroom*
9:45–11:30 a.m.	Poster Viewing	*Palms Ballroom*
10:30–11:30 a.m.	Guest Speaker: **Studying the Yeasts of Yesterday to Generate the Beer Yeasts of Tomorrow**	*Everglades Ballroom*
11:30 a.m.–1:30 p.m.	Exhibits, Posters, and Lunch	*Palms Ballroom*
	12:00–12:30 p.m. Even-numbered poster authors at poster	
	12:30–1:00 p.m. Odd-numbered poster authors at poster	
1:30–2:00 p.m.	Poster Take-Down	*Palms Ballroom*
1:40 p.m.	Quilt Raffle Closes	*Palms Foyer*
1:45–3:30 p.m.	Technical Session 6: **Sensory**	*Everglades Ballroom*
	Moderator: Lindsay Barr, New Belgium Brewing Co.	
	1:45 p.m. 18. C. Hahn. A comprehensive evaluation of the nonvolatile chemistry affecting the bitterness intensity of highly hopped beers	
	2:10 p.m. 19. R. Kerpes. The impact of extracellular long-chain free fatty acids on the aroma profile of a gluten-free barley malt beer produced by means of endogenous maltpeptidases	
	2:35 p.m. 20. S. Miyashita. Effect of aroma on *kire* of beer	
	3:00 p.m. 21. K. Siebert. Sense vs. analysis	
1:45–3:30 p.m.	Workshop: **Application of Chromatography to Brewing Analysis**	*Camellia AB*
1:45–3:30 p.m.	Workshop: **Building a Research Program for Craft Breweries**	*Caloosa Ballroom*
1:30–4:00 p.m.	Exhibit Move-Out	*Palms Ballroom*
3:45–4:30 p.m.	Special Session: **Beer Abby**	*Everglades Ballroom*
4:30–7:00 p.m.	Hospitality Room Open	*Island Room*
7:00–9:30 p.m.	**Suds & Sand Beach Party**	*Everglades Pool Deck and The Cove Beach Area*
9:30–11:30 p.m.	Hospitality Room Open	*Island Room*

Tuesday Highlights

Workshop: Hops II - Interfacing with the Hop Industry

8:30–10:15 a.m. • Everglades Ballroom

Darren Gamache, Virgil Gamache Farms Inc.; Timothy Kostelecky, John I. Haas, Inc.; Tiffany Pitra, Hopsteiner

This workshop will cover everything and anything hops. Given the tremendous emphasis on hop-forward beers—it is important for brewers and quality managers to understand the perspective of hop farmers and suppliers. Presenters will share their experiences on how best to interface with their portion of the business in such a way that maximizes benefits. A hop supplier will provide guidance around purchasing hops, evaluating hops, and using hops efficiently. A hop breeder will touch on new techniques and approaches to breeding and experimental evaluation. A hop farmer will discuss issues pertaining to hop quality from a growing perspective as well as how to maximize the efficacy of the relationship between farmer and brewer. Don't miss out on this workshop—go into the 2017 harvest with more knowledge to sniff out the best hops!

Workshop: Technical Barrel Aging

8:30–10:30 a.m. • Caloosa Ballroom

Steve Anderson, Ballast Point Brewing Co.; James Conery, Sierra Nevada Brewing Co.; Dean Katzung, E. & J. Gallo Winery; Bruce Pan, E. & J. Gallo Winery; Christy Thomas, Vicard G7 Cooperage; Lauren Zeidler, Ballast Point

How do barrel toasting and coopering impact oak flavor? What do I need to think about as I increase the volume of my barrel-aged beers? Can I predict how oak aging will affect my beer? What do I need to know about oxygen ingress? Are there benefits to using different types of barrels and oak? As beer barrel aging continues to grow in popularity, there is increased attention to oak flavor and aroma impact. This workshop brings together experts from the wine, coopering, and brewing industries to discuss oak chemistry and sensory qualities, blending decisions, and quality considerations when using barrels. Get all your oak questions answered, put your taste buds to work, and start thinking about barrel-aged beers in a different way.

Guest Speaker: Studying the Yeasts of Yesterday to Generate the Beer Yeasts of Tomorrow

10:30–11:30 a.m. • Everglades Ballroom

Kevin Verstrepen, KU Leuven

The common brewer's yeast, *Saccharomyces cerevisiae*, is used in a broad range of industrial applications, from the production of beer, wine, and bread to biofuels and pharmaceuticals. Interestingly, there are hundreds of different industrial yeast strains, but their origins and specific characteristics are largely unknown. Kevin has combined large-scale phenotyping with genome sequencing to track the genealogy and evolution of today's industrial yeasts. Using this knowledge allowed him to set up large-scale breeding programs to generate superior variants that increase production efficiency and expand the range of yeast-derived products and aromas, allowing more efficient beer fermentation, the production of superior beers, and the creation of novel products.

Kevin Verstrepen is professor in genetics and genomics at KU Leuven and group leader in Systems Biology at VIB (Flanders Institute for Biotechnology). He serves as the director of the VIB Center for Microbiology, director of the Leuven Institute for Beer Research, and Honorary Professor at Nottingham University. In 2017, he was appointed as scientific director of the VIB Center for Microbiology, where he leads a team of 100 researchers in the different laboratories at VIB that focus on microbiology. Read full biography at asbcnet.org/meeting.

Workshop: Application of Chromatography to Brewing Analysis

1:45–3:30 p.m. • Camellia AB

Adam Heuberger, Colorado State University; Joseph Palausky, Boulevard Brewing Co.; Stacey Williams, New Belgium Brewing Co.

Liquid chromatography (LC) and gas chromatography (GC) instrumentation have become common tools found in brewing laboratories with applications ranging from quality assurance to advancing brewing science. This workshop will provide a basic introduction to chromatography, including the fundamentals of liquid and gas chromatography. Example applications from the *ASBC Methods of Analysis* along with other commonly used methods will be reviewed. In addition, advanced applications of GCMS including statistical data processing will be covered. A question and answer session will be held at the end of the workshop.

Workshop: Building a Research Program for Craft Breweries

1:45–3:30 p.m. • Caloosa Ballroom

Lucas Chadwick, Bell's Brewery, Inc.; Meghan Peltz, Sierra Nevada Brewing Company; Nils Rettberg, VLB Berlin; Joe Williams, University of California—Davis

Building experiments to analyze specific process parameters can be challenging, but it doesn't have to be. Utilizing existing literature and the scientific method, hypotheses can be created and tested in a systematic way that allows for the generation of usable data. The panel will present and discuss the creation of a basic research program utilizing existing capabilities within the brewery, outside laboratories, and university/industry partnerships. Additionally, the selection of an interdepartmental team to formulate a research hypothesis and proper setup of experiments will be presented within the context of case studies from the brewing industry.

Process improvements don't have to be based on feelings or guesses; experiment, monitor, and repeat until consistent results are achieved.

Special Session: Beer Abby

3:45–4:30 p.m. • Everglades Ballroom

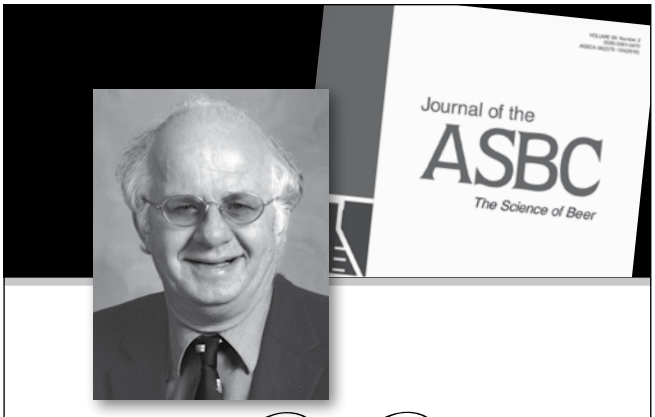
Moderators: Christine White, Molson Coors Brewing Co.; Aaron Golston, Lagunitas Brewing Co.

Do you have a burning question about brewing science? Throughout the meeting prior to this session, post your questions on the Beer Abby board in the Palms Foyer and get them answered by your colleagues, both on the panel and in the audience.

Suds & Sand Beach Party

7:00–9:30 p.m. • Everglades Pool Deck and The Cove Beach Area

Surf's up at the Suds and Sand Beach Party! We know you're dying to wear that Hawaiian shirt you've been hiding in the bottom drawer. Hang loose and grab some tasty munchies and refreshing libations. It will be our last call for fun as we wrap up Tuesday.



Thank you

to Charles W. Bamforth
for your many years as Editor in Chief
of the *Journal of the ASBC*.

Interested in working on the *ASBC Methods of Analysis*?

Reach out to the Technical Committee!

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  – *Beer and Analytical Methods*
- **Nils Rettberg,** VLB Berlin
  – *Advanced Analytical Methods*
- **Eric Welten,** HEINEKEN
  – *EBC Representative*

Wednesday, June 7

7:45–10:30 a.m.	Registration Open	*Palms Foyer*
8:15–10:00 a.m.	Technical Session 7: **In-Process QA**	*Everglades A*
	Moderator: Xiang Yin, Rahr Malting Co.	
	8:15 a.m. 22. J. Biering. Reliable scale up/scale down in process development—New possibilities to close the gap between lab, pilot brewery, and industrial scale	
	8:40 a.m. 23. B. Gadzov. In-process sensory and beer flavor stability	
	9:05 a.m. 24. A. Mundkur. External risks to beer flavor quality	
	9:30 a.m. 25. D. Russey. Simplify QAQC analyses and decision making with open source software	
8:15–10:00 a.m.	Technical Session 8: **Microbiology**	*Harbourview (1st Floor)*
	Moderator: Caroline Pachello, MillerCoors	
	8:15 a.m. 26. L. L. Chan. A novel concentration and viability detection method for *Brettanomyces* using image cytometry	
	8:40 a.m. 27. A. Decloedt. Barley fungi and their mycotoxins in beer production	
	9:05 a.m. 28. K. Suzuki. Rediscovery of *Lactobacillus pastorianus* Van Laer 1892, a beer spoilage *Lactobacillus* species named in honor of Louis Pasteur, and studies on its extraordinarily unique culturability	
	9:30 a.m. 29. E. Thomson. Worse than we thought: A *Megasphaera cerevisiae* isolate is able to spoil full-strength beer	
9:00–11:00 a.m.	Workshop: **Executing and Understanding Sensory Thresholds in Beer**	*Caloosa Ballroom*
10:15–11:30 a.m.	Technical Session 9: **Hops II**	*Harbourview (1st Floor)*
	Moderator: Timothy Kostelecky, John I. Haas, Inc.	
	10:15 a.m. 30. A. Baillo. Dry hopping and stirring pellets increases vicinal diketones and lowers apparent extract	
	10:40 a.m. 4. S. Lafontaine. Evaluating hop chemistry and its contribution to hop aroma intensity in dry-hopped beer	
	11:05 a.m. 32. M. D. Zunkel. Impact of hop pellet processing in regard to flavour contribution in beers late and dry hopped with U.S. Cascade hops	
11:30 a.m.–1:00 p.m.	**Beer-lympics**	*Everglades Ballroom*

Wednesday Highlights

Workshop: Executing and Understanding Sensory Thresholds in Beer

9:00–11:00 a.m. • *Caloosa Ballroom*

Tom Shellhammer, Oregon State University

Sensory threshold measurements are carried out either to test the sensitivity of panelists to a certain compound or to understand the magnitude of impact an individual compound may have on beer flavor. This workshop will guide participants through the steps to carry out sensory threshold measurements using Sensory Analysis-9: Threshold of Added Substances—Ascending Method of Limits Test from the *ASBC Methods of Analysis*. Participants will learn about considerations in designing and executing the study and work through the statistical analyses of threshold data. We'll compare this approach to others, such as the ASTM E-1432, Standard Practice for Defining and Calculating Individual and Group Sensory Thresholds from Forced-Choice Data Sets of Intermediate Size. Participants will perform threshold measurements on diacetyl and acetaldehyde in beer and will leave the workshop knowing their own personal threshold concentrations for these two compounds.

Beer-lympics

11:30 a.m. –1:00 p.m. • *Everglades Ballroom*

Close out the meeting with this ASBC-style networking event, where you will make connections while engaging in friendly competition! Build your network, scout for talent, and lead your team to victory. Come see what's in store at the Beer-lympics!

Cheers to You, ASBC Corporate Members

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1
MetabAromics: A semi-targeted approach to beer analysis
Torres, L. N.[1] and CHADWICK, L.[1], (1)Bell's Brewery, Inc., Galesburg, MI, U.S.A.

Gas chromatography coupled with mass spectrometry (GCMS) is becoming a practical analytical tool for smaller and smaller companies throughout the food and beverage industries. The wealth of information provided by GCMS, coupled with continuous improvements and decreasing costs of instruments, will ensure that more and more (and smaller and smaller!) breweries will adopt this technology. Without question, stable isotope dilution assays (SIDA) are the gold standard for quantitative mass-spectrometric analyses. MetabAromics (MA) is proposed as a complementary approach to SIDA, as a means of maximizing the value of mass chromatograms, in particular for analytes where analytical standards are not available. SIDA provides excellent precision and accuracy for a handful of key target molecules, whereas MA provides information about all detectable analytes. This presentation will detail the process of establishing the MA platform, from collating literature information for over 800 volatile compounds known from hops and/or beer, through optimization of data acquisition and processing parameters. The presentation will also highlight some of the inherent risks of the MA approach.

Lucas Chadwick received a B.A. degree in chemistry from Kalamazoo College in Kalamazoo, MI. He went on to earn his Ph.D. degree from the University of Illinois at Chicago (UIC), where his work at the UIC/NIH Center for Botanical Dietary Supplements Research focused on the pharmacognosy of hops. After a post-doctoral appointment in the Botanical Center, he began employment at Kalsec, Inc., where he worked on natural antioxidants and process development. In 2006, Luke co-founded Wrightwood Technologies and was subsequently awarded a Small Business Innovative Research Grant to automate a preparative chromatographic technique known as countercurrent chromatography. Luke joined Bell's Brewery, Inc. in 2010 as quality/lab manager and has served as senior scientist at Bell's since 2015.

2
Bridging significant gaps? Application of a metabolomics platform in beer quality control
RETTBERG, N., VLB Berlin, Berlin, Germany

Consistency is a major concern of industrial brewing. In order to ensure stable beer quality, multiple instrumental, as well as sensory techniques, are applied. Whereas sensory is able to provide a rather comprehensive picture with respect to taste and smell, data of instrumental analysis (depending on brewery size) can be rather fragmentary. In order to fully assess relevant chemical properties of beer, numerous targeted methods, ranging from simple (bitterness, foam, color, carbonation, haze, etc.) to sophisticated (terpenes, esters, carbohydrates, etc.), might be applied. However, product characterization remains rather incomplete, and data is frequently unable to reflect variations detected in sensory. In contrast to common targeted methods of analysis, (untargeted) metabolomics aim at a comprehensive characterization of substances present in a sample. Powerful instrumental assays combined with bioinformatics enable a detailed study of (bio) chemical processes, as well as the detection of potential variations between sample sets (e.g., fresh vs. old). In the last decade the significance of metabolomics has been underlined by valuable research in crop, food, and life sciences. The number of beer-related publications is increasing accordingly. Through the eyes of a practical brewer, the application of metabolomics in quality control appears to be promising. Especially its objective of being comprehensive seems helpful to overcome the major drawbacks of classical targeted analytics. In order to evaluate the power and efficiency of metabolomics in quality control, a metabolomics platform (HS-SPME-GC-MS and LC-Q-ToF-MS) was applied to samples of a single brand of pilsner beer produced at four different production sites. The data set, collected over a trimester of production, is compared to results from standard and special beer analysis, as well as from sensory evaluation. By this, time- and production site-related variations in volatile and non-volatile metabolite profiles were linked to changes in quality characteristics of the brews. Thus, the paper will answer the question, which significant gaps can be bridged by metabolomics and which value can (yet) be added to quality control in brewing, respectively.

Nils Rettberg (born 1983) is a trained brewer and maltster, holding a diploma in biotechnology with a focus on brewing science from TU Berlin (Germany). Initiated by his diploma thesis on "Flavor Active Epoxydecenals from Lipid Oxidation" he developed a deep interest in the analysis of molecules that make beer taste either terribly good or horribly stale. From 2011 to 2014 Nils performed his doctoral thesis on "Comprehensive Analysis of Hop Secondary Metabolites." Simultaneously, he was a research associate at TU Berlin (Chair of Bioanalytics) and VLB Berlin (Research Institute for Special Analyses), where he was involved in both research and teaching. In January 2015 Nils became head of the VLB Research Institute for Special Analysis. Since October 2015 Nils has been in charge of the VLB Research Institute for Instrumental Beer and Beverage Analysis.

3
Mapping the microbiome of malted barley (from varied regions, varietals, and harvest years) and wort soured using the barley
YOUNG, J., Blue Owl Brewing, Austin, TX, U.S.A. and Bochman, M. L., Indiana University, Bloomington, IN, U.S.A.

Adding sourness to wort fundamentally changes one of the key elements in the flavor profile. Wort souring is being used by many breweries—from nano to nationally distributed production breweries. Studies are being conducted using DNA sequencing to determine the species and relative abundance of barley and grain-soured wort bacteria, as well as NMR analysis to determine the alcohol/organic acid wort profile. Results will help us better understand and utilize naturally occurring bacteria found on malted barley for the purposes of wort souring. The results of these studies will be presented, and the topics include 1) mapping the native microbiome on freshly malted barley from multiple sources (3 different continents; 2 different malting facilities with the same barely); 2) tracking the growth of bacteria in wort after being inoculated with the malt; 3) assessing the organic acid composition in the wort, post-souring; and 4) practical brewing consideration in reference to the dominant souring bacteria determined in #2 (wort clarity and fining, yeast selection and harvesting [a study done with Kara Taylor from White Labs will give details on harvesting yeast from wort-soured beers], and beer fining). DNA sequencing

was conducted on pilsner malt, as well as wort soured with the malt to determine the species and relative quantity of bacteria, wild yeast, molds, etc. The malt was selected with the assistance of Bob Hansen, technical services manager of Briess Malting Co., and it was determined that pilsner malt was the most ideal malted barley to study. Freshly harvested 2016 barley malted at two different Briess malting plants was investigated to compare geographic variation in the malt microbiome. Additionally, fresh pilsner malt from Weyermann and ~6 month pilsner malt from Patagonia will be compared for the same purposes. DNA sequencing data will be presented to identify and quantify the thriving microbes in wort that is inoculated with the malt samples from #1, using conditions established by Jeff Young at Blue Owl Brewing. Soured wort samples were analyzed for composition of alcohols and organic acids using NMR assays by Dr. John Edwards of Process NMR Associates, LLC. The metabolites of the bacterial fermentation will help illuminate and correlate the activity of the dominant bacteria discovered from the DNA sequencing. All of the data collected from the DNA sequencing and NMR analyses will be related to how a professional brewery of any size can harness natural bacteria sourced from malted barely. Even though the source inoculant is easily accessible and practically free (Blue Owl spends less than $5 to sour 30 barrels of wort), the low pH, bacterial load, and high levels of acidity necessitate a reassessment of all steps of the brewing process—from wort turbidity to hop oils, yeast selection, harvesting, and fining.

Jeff Young has been brewing for over a decade and was previously an analytical chemist at a pharmaceutical company. Jeff's passions for art, science, and engineering come together in the brewhouse! Jeff left his previous brewery, Black Star Co-op Pub and Brewery, to focus solely on sour-mashing and the novel, seemingly endless possibilities of integrating sourness in any beer style.

4

Evaluating hop chemistry and its contribution to hop aroma intensity in dry-hopped beer

LAFONTAINE, S.[1] and Shellhammer, T. H.[1], (1)Oregon State University, Corvallis, OR, U.S.A.

Many factors upstream of the brewery, such as raw material attributes (i.e., total oil content and composition) and processing factors (i.e., harvest maturity), influence hop aroma performance in beer. To investigate the influence of these factors on the dry-hop aroma intensity of multiple cultivars, 63 unique dry-hopped beers were prepared using different lots of Cascade from the 2014 and 2015 harvests, and 12 dry-hopped beers were prepared for both Centennial and Chinook using samples collected from the 2015 harvest. We confirmed that total oil content was not a strong predictor of overall hop aroma intensity (OHAI) in dry-hopped beer for Cascade ($R^2 = 0.20$ for 2015 harvest samples) and similarly for Chinook ($R^2 = 0.01$). However, there seemed to be a suggestive relationship between total oil content and OHAI for Centennial ($R^2 = 0.38$). Much more significant positive correlations were observed between the hop oil analyte concentrations (most notably linalool, geranial, rho cymene, geranyl acetate, and geraniol) with OHAI for the 2015 harvest Cascade samples. In contrast, the 2014 harvest Cascade samples yielded negative correlations for linalool and geranial with OHAI. Significant farm and harvest maturity effects were also observed in the Cascade samples between the two harvest years, with higher oil and later harvested hops showing a higher aroma potential at one farm over the two years. Yet, this same observation was contradicted in other farms and years. Turning to the Centennial and Chinook cultivars, it was interesting to observe a significant positive correlation between myrcene and OHAI for Centennial ($R^2 = 0.76$). In contrast to Cascade, this indicates that myrcene along with other hop oil analytes (specifically, limonene and alpha+beta pinene) may be markers for Centennial dry-hop aroma intensity. For Chinook, linalool and rho cymene appear to be potential positive candidates for aroma intensity, while geranial, trans-farnesol, caryophyllene, alpha-humulene, and E-B-damascenone were negatively correlated to Chinook aroma intensity. This information provides a greater understanding about which hop oil analytes correlate with OHAI in dry-hopped beer. Ultimately, we believe that this information is going to help the industry best designate hops for aroma purposes and understand the variation that exists within and between cultivars.

Scott Lafontaine is a graduate research assistant at Oregon State University and a member of Dr. Thomas Shellhammer's laboratory. His research focuses on determining factors in hops that drive their dry-hop aroma performance in beer. He assists in the teaching of residential and continuing brewing analytical and quality education courses at OSU. Prior to joining the Shellhammer team at OSU, he received his M.S. degree in Chemistry at OSU in 2015, during which his studies focused on analytical environmental chemistry.

5

The black currant-like smelling aroma compound 4MMP—Influence of variety, provenance, and processing on the concentration in hops

REGLITZ, K., Deutsche Forschungsanstalt für Lebensmittelchemie, Freising, Germany

To increase the shelf life of beer and enhance its bitterness, hops are traditionally added at the beginning of the wort-boiling process during beer production. To impart a hoppy aroma, a second portion of hops must be added later in the process, typically after wort boiling (late-hopping) or during conditioning (dry-hopping). One of the key compounds for the hoppy aroma in beer is citrusy smelling linalool. Depending on the variety, further hop compounds can be transferred into the beer in aroma-active amounts. One of these is black currant-like smelling 4-mercapto-4-methyl-2-pentanone (4MMP), which exhibits an odor threshold as low as 0.00055 µg per liter of beer. The aim of this study is to get a deeper insight into the concentration of 4MMP in different hop varieties, its variability and its behavior during hop processing. As a first step, a sensitive analytical approach based in a stable isotope dilution assay (SIDA) in combination with the selective enrichment of thiols on mercurated agarose gel and GC×GC-TOFMS was developed. Application to more than 80 samples of hops covering 45 different varieties from the U.S. and Europe revealed 4MMP concentrations between 0 and 114 µg/kg and allowed, therefore, an estimation of the impact of variety and provenance on the 4MMP contents in hops. Further experiments were focused on changes in 4MMP concentrations during hop processing. Results indicated that the temperature and the pelletizing process did not have a significant influence on the 4MMP concentration.

Klaas Reglitz is a research scientist in the group of Martin Steinhaus at the Deutsche Forschungsanstalt für Lebensmittelchemie, Leibniz Institut (German Research Center for Food Chemistry, Leibniz Institute) in Freising-Weihenstephan, Germany. He studied brewing and beverage technology at the Technische Unversität, München (Technical University of Munich) and received a Ph.D. degree in food chemistry for a thesis on the "Influence of Composition and Structure on the Release of Aroma Compounds from Foamed Milk Model Systems." Klaas is currently working on the identification of odor-active compounds in different materials, including hops, orange juice, and consumer products.

6

Effect of hop harvest date on the thiol contents in hop cone

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In recent years, many hop varieties with very unique aromas have been bred and grown. Those hops are often called "flavor hops" and give the characteristic fruity flavor to finished beers. Sapporo Breweries Ltd. has investigated the influence of volatile thiols on hop aroma. We mainly focused on two volatile thiols, 4MSP (4-methyl-4-sulfanylpentane-2-on) and 3S4MP (3-sulfanyl-4-methylpentan-1-ol). On one hand, it was reported that 4MSP has a black currant-like odor and 3S4MP has a grapefruit or white wine-like odor. On the other hand, there is little data on a relationship between cultivation technology and quality of hops, which has not sufficiently been investigated. In previous studies, it has been thought that later harvest date results in higher essential oil contents and that the concentration of alpha acids is generally maximized before that of essential oils. However, the impact of hop harvest date on the thiol content in hop cones has not yet been investigated. In this study, we focused on 'Furano Beauty' and 'Furano Magical' that were bred by Sapporo Breweries Ltd., and 'Cascade'. These hops were harvested at three harvest times (45 days (normal), 65 days and 75 days) within a 4 week interval. We measured alpha acids and essential oils using American Society of Brewing Chemist standard methods of analysis and the volatile thiols by gas chromatography-tandem mass spectrometry (GC-MS/MS). As a result, with delayed harvest date, the content of 4MSP showed almost no change or slightly decreased, while the content of 3S4MP increased by several times. In addition, we confirmed that the content of 3S4MP in the beer brewed with 65 day hops was several times higher than those in the beers with 45 day hops. In addition, 45 day hop beer and 65 day hop beer were clearly distinguished by sensory tests. From these results, we would propose a method to control the content of 3S4MP in hop cone using only changes in harvest date.

Mitsuhiro Uemoto received a master's degree from Kyoto University in Japan, where he majored in plant cell biology. He began employment with Sapporo Breweries in 2012 as a hop breeder and researcher in the Bioresources Research & Development Department. He contributed to breeding 'Furano Honoka', 'Furano Rosa', 'Furano Flora', and 'Furano Blanc'. He is also engaged in research on the genetic marker construction of the bitter acids and essential oils in hop.

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Monitoring and control of onion-like off-flavor component precursor in large-scale brewing

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There are a number of studies reported by Japanese breweries on technological developments for the control of sulfur off-flavor components in beer. These technologies have been necessary to allow the brewing of low-malt beer with low nutrients, such as amino acids, in the wort, which has a lower tax rate than normal beer under the Japanese Liquor Tax Law and are also important to increase the "clearness" and "smoothness" of products, which are preferred by Japanese consumers. We have also reported some technological results in this field. These include both analytical technologies to detect and quantify the off-flavor components, even at low concentrations, and production technologies to control the formation of these components in the brewing process through the introduction of analytical methods to monitor the process. As one of such sulfur components, we focused on 2-mercapto-3-methyl-butanol (2M3MB). It imparts an unpleasant onion-like flavor to beer, and variations in the amount were observed among several breweries, which may lead to sensory variations. Recently, we purified the precursor of 2M3MB from hops and identified the compound as 2,3-epoxy-3-methyl-butanal (EMB). By monitoring 2M3MB and EMB in the brewing process, we found variability in both the amount of EMB in wort and the conversion rate of EMB to 2M3MB among several of our breweries. In this presentation, we discuss further monitoring of the brewing process. We monitored the levels of EMB from the start of boiling to the start of fermentation at two breweries (1,250 and 700 hL/brew) with documented variability in 2M3MB. The precursor was detected from hop dosing at the start of boiling and increased through the boiling, whirlpool, and aeration processes. This supports the hypothesis that 2M3MB is derived from hops and that the uptake of oxygen is involved in its formation. In addition, differences between the two breweries were observed, particularly in the initial boiling step and in the whirlpool waiting phase. Differences in the brewing process and equipment that may cause variations between the breweries will also be discussed. The results may provide a clue to determine the underlying reasons for variations in 2M3MB production and may allow us to improve our processes to control the amount of 2M3MB in beer.

Taku Irie received an M.S. degree in engineering from the University of Tokyo in 2000 and began working for Asahi Breweries, Ltd. After a few years as a technological staff member in the Packaging Section in some breweries, he has been in charge of the technological development of brewing at the Production Technology Center and Fukushima brewery. From 2012 to 2014, he worked at the Lehrstuhl für Brau- und Getränketechnologie, TU München, as a guest researcher. Since April 2014, he has again been working at the Ibaraki R&D Promotion Office, Production Technology Center.

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New technologies for development of citrus-based ready-to-drink (RTD) alcoholic beverages that maintain freshness

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The alcoholic beverage market in Japan is in a period of rapid transition with the ready-to-drink (RTD) market expanding in place of beer. RTDs are carbonated drinks with less than 10% alcohol, containing fruit juice, acidifiers, sweeteners and flavor compounds. The RTD growth is driven by prices cheaper than beer because of the tax rate, and above all, by the fact that various RTD flavors can meet a wide range of customer needs. In Japan, the RTD market is larger than that of beer cocktails, and thus all major Japanese beer companies are making enormous efforts to develop new RTDs. Recently, Japanese customers are increasingly demanding the feeling of more natural juice and a fresh aroma from RTD products. These trends are particularly noticeable with popular citrus flavors such as lemon and grapefruit. This is why we developed RTD products that have an even fresher feeling of fruit juice. First of all, we explored major flavor components contributing to a feeling of natural juice by sensory evaluation and non-target GC-MS with multivariate analysis software. The results showed that citral and methylheptenone contribute to the enhanced feelings of natural juice and freshness. Citral is an important flavor component among citrus oils. But it is highly unstable in beverages and converts into off-flavors such as *p*-cymene (gasoline-like), *p*-methylacetophenone (bitter-almond-like) and *p*-cresol (phenolic). The deterioration of citral proceeds during the

storage of products, resulting in an undesirable alteration of the product flavor profile. On the other hand, methylheptenone has a green aroma with high flavor stabilizing properties, and, combined with citral, this component is considered to maintain a feeling of freshness. Next, we investigated countermeasures to prevent citral off-flavor formation. Similar to beer, off-flavors are generated through oxidation-triggered deterioration. Therefore, we searched effective antioxidants from 200 polyphenol-containing materials. Some plant extracts, such as olive fruit extract, were found to have a considerable inhibitory effect on off-flavor generation. Furthermore, we successfully identified the optimal product pH to minimize the acid-induced circularization of citral. Through antioxidant usage and pH optimization, it became possible to develop a product that maintains the fresh feeling of natural juice even after long-term storage. As shown above, we have been able to create revolutionary RTD products with new values of freshness for customers. Strikingly, sales registered in the first year were the highest among all the RTD brands that have been launched for the past 10 years in Japan.

Mutsumi Segawa joined Asahi Breweries, Ltd. in 2015. Since then, she has developed RTD products and been involved in technological development of fresh flavor preservation in products. Before joining Asahi Breweries, Ltd. she received a master's degree in biological sciences from Tokyo Institute of Technology in 2015.

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Influence of aging time on flavor and relevant compounds of barrel-aged beer

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Barrel-aged beer having a peculiar flavor originating from the wood are attracting attention not only in its birthplace (Belgium and Germany), but also in the United States, as well as micro-breweries in Japan. Various parameters, such as wood origin, the history of the barrel, aging time, toasting condition, and the type of beer aged in the barrel could exert influence on the flavor characteristics and intensities of barrel-aged beer. Among these parameters, the relationship between aging time and flavor of barrel-aged beer was especially focused on in this research. Comparison of sensory evaluation and compound analysis between beer samples with different aging times were implemented to control barrel-aged beer flavor. It was confirmed that there were significant differences between beer samples with different aging times from 0 to 24 weeks. The initial aging time (0–4 weeks) had slight changes in flavor characteristics, although after 4 weeks, there were remarkable changes in flavor profiles of beer. It was assumed that compounds relating to flavor characteristics that were extracted from the barrel don't easily dissolve into the beer in a comparably short aging time, and an obvious barrel-aged flavor could be obtained by aging for a longer time. At first, six flavor attributes of barrel-aged beer were extracted by comparing beers between before and after barrel-aging. Those were fullness, coconut-like, vanilla-like, woody, phenolic, and oxidized malty, and were scored. To examine the compound profile relating to flavor attributes, sensory analysis adding fractions of aroma compounds extracted from barrel-aged beer that were discriminated by polarity were implemented. As a comprehensive chemical analysis, sniffing-GC and GC×GC-TOF/MS of fractions that especially contributed to typical barrel-aged flavor were implemented. The key compounds were identified, and the behavior of those during aging time were examined. Barrel-aged flavor could be perceived even though the aging time is 0 to 4 weeks, and the score of coconut-like and vanilla-like were comparably high. On the other hand, after 4 weeks, the score of coconut-like and vanilla-like were low, and that of oxidized malty and phenolic were high. As a result of compound analysis, characteristic compounds could be narrowed down to 10, including γ-octanolactone and γ-nonalactone, which are wood's volatile oil compounds, besides vanillin, a compound yielded by the heat decomposition of lignin, which is one of the major structural compounds of wood. By evaluating the quantitative data of the behavior of these compounds during aging , 4-ethylguaiacol having a phenolic feature was minimized (below 1.2 µg/L) when the aging time was 0 to 4 weeks, and increased remarkably after 4 weeks. *Trans*-oak lactone, which has a sweet coconut feature, could be perceived (30 µg/L) within 4 weeks. These results corresponded well to the sensory evaluation scores. In conclusion, it was confirmed that controlling of the aging time enables big changes in flavor of barrel-aged beer.

Anna Shimmura graduated from Osaka University with a master's degree of chemical engineering in 2014. After joining Suntory, she worked for three years in the Beer Development Department of Suntory Beer Limited. She is engaged in research on the development of brewing technology and flavor science of beers, such as barrel-aged beer and beer using colored malts.

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Comparison of the flavor and aroma compounds present in aging lambic beer

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Lambic beer is one of the oldest styles of beer still being produced today using spontaneous fermentation. Gueuze is a style of lambic beer that blends "young" (1 year old) and aged (2+ years old) beers. Little is known about the development of the volatile and semi-volatile compounds in lambic beer during aging. SPME with GCMS was used for extraction and identification of volatile and semi-volatile compounds from 3-, 6-, 9-, 12-, and 28-month-old commercial samples of lambic beer. Compounds were identified using standardized retention time and mass spectra of standards. GC-O was used to characterize the aroma profiles of the samples. A total of 42 compounds were identified using GC-MS. Seventeen of the 42 compounds identified in the various aged samples have been previously reported in lambic beer. Ethyl lactate, ethyl acetate, 4-ethylphenol and 4-ethylguaiacol were identified in the 9-, 12-, and 28-month-old samples. These four compounds have been linked to the microorganism *Brettanomyces*. Twenty-one aroma active compounds were identified using GC-O. As the age of the gueuze samples increased, a larger number of aroma compounds were identified by the panelists; compounds identified increased from seven for the 3-month-old samples to nine for the 6-month-old samples, and eleven for both the 9- and 12-month-old samples, and seventeen for the 28-month-old samples.

Katherine Witrick has appointments in chemistry and biochemistry and the Fermentation Science Institute, with animal science, food and nutrition being her primary appointment and tenure home. Katherine earned her Ph.D. degree in food science and technology, with an emphasis in analytical chemistry, at Virginia Polytechnic Institute and State University (Virginia Tech) in Blacksburg, VA. Her degree focused on flavor development in lambic degrees. She received her post-doctoral training from Virginia Tech. Prior to coming to SIU she worked at SweetWater Brewing Company (Atlanta, GA) in the Quality Control Department. Her research currently focuses on the use of analytical and sensory techniques

to look at how flavor and aroma compounds develop in fermented beverage systems.

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Shelf life and consistency of active dry yeast for breweries

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Nowadays, active dry yeast (ADY) is an attractive and easy tool for beer production and/or diversification. Nevertheless, literature is poor in terms of information regarding consistency of ADY and its real shelf life. Therefore, brewers have a limited visibility on the storage life of ADY without impacting its initial performances. The purpose of this lecture is to present results from different independent studies on the consistency of ADY and its real shelf life across different strains and batches. Ten commercial ADY were considered in forced aging tests, and 2 ADY were studied following natural aging (3 years). Yeast performance was evaluated by analysis of fermentation profile, attenuation level and volatiles production. For some yeasts, sensory analysis was performed after bottling. The results of this study show that after more than 3 years, there are no significant differences between aged and freshly produced ADY in terms of fermentation performance and beer quality.

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The relationship between brewery yeast handling and mitochondria development

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Yeast quality is integral to ensuring consistency during fermentation and has a significant and direct impact on the final product. While yeast quality is often defined by the physiological characteristics or microbiological purity of a culture, the terminology also incorporates a variety of additional metrics, including the capacity of cells to function to their maximum capacity. One of the major factors that can cause populations to ferment poorly is the accumulation of mutants, arguably the most frequent of which is the "petite" mutation. Petite mutants are caused by damage to mitochondrial DNA (mtDNA) and can be found in two forms: where mtDNA is present but exists as a series of non-coding regions (ρ), and where mitochondria are completely lacking from the cell (ρ0). These can be observed in most brewing yeast cultures at approximately 1–3% of the total cell count. However, in certain circumstances the number of petites can exceed 10–20%, at which point they begin to have a major negative impact on both the fermentation process and the final product. Fermentations conducted using cultures with an abnormal number of petite cells are typically slow with a less efficient conversion of sugar to alcohol, and produce beer with a range of flavor defects. The underlying causes behind the development of the petite mutation in brewing yeast are currently poorly understood. In this study we aim to elucidate the relationship between yeast handling practices and the development of the petite mutation, using a number of both lager and ale production strains. Specifically, we investigate conditions associated with propagation, fermentation and yeast storage and determine the impact of these on the number of mitochondria per cell, mitochondrial development and inheritance, and overall mtDNA integrity. The data presented will demonstrate the changes that occur to mitochondria during active growth and fermentation, and the precise impact of process stage on mitochondria number. We also show how mitochondria morphology changes during fermentation in response to stress factors associated with industrial processes. Finally, we determine why some industrial strains have a higher propensity to form petite mutants than others, and reveal which brewery yeast handling practices have the greatest influence on promoting mtDNA damage. It is anticipated that this data will further our understanding of the petite mutation and it is hoped that in the future it will be possible to remove or mitigate their occurrence and impact during brewery fermentations.

Eoin Moynihan is an SABMiller-funded Ph.D. student at the International Centre for Brewing Science at the University of Nottingham, U.K. Eoin holds a B.S. (honors) degree in plant biotechnology (2009) and an M.S. degree in applied biotechnology (2013), both obtained at University College of Cork, Ireland. During his M.S. degree studies, he focused on yeast diversity throughout spontaneous cider production and now is examining the role of mtDNA in brewing yeast.

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Variation within brewing yeast populations

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Brewery fermentations are unique in that it is common practice to harvest (crop) the yeast at the end of fermentation and re-inoculate (repitch) the culture into a fresh batch of wort in a process known as serial repitching. Repitching yeast often results in a reduction in yeast quality over time, although the extent to which this occurs depends on the individual yeast strain and the number of repitchings (generations). It is well known that some yeast strains can be reused many times with little apparent effect on product quality. However, other strains are less tolerant of repitching, and these populations can display genetic and/or phenotypic drift over time, ultimately influencing the capacity of the population to produce beer within product specifications. Although brewing yeast cultures are typically considered to comprise cells that are all identical in nature, it is known that microbial populations often exhibit differences between individuals. At the basic level, this may result in a decreased fitness to ferment, resulting in inconsistent fermentations, extended vessel residence times and potentially necessitating changes to downstream processing, leading to increases in overall manufacturing costs. In this study we investigate aspects of population variability to determine the underlying causes behind changes to brewing yeast populations. This includes the potential for selection during repitching, the genetic stability of production strains, and the analysis of population heterogeneity in ale and lager production strains. Yeast populations were characterized using a variety of DNA fingerprinting methods, and heterogeneity was assessed through analysis of resistance to key stress factors, as determined via a series of physiological assays based on growth behavior. During this presentation, we show data indicating the degree of heterogeneity within brewing yeast populations, specifically related to physiological attributes, stress tolerance and key performance indicators. We also explore the relationship between fermentation conditions and population heterogeneity, and the potential for the selection of cells based on this. Finally, we provide details on whether population heterogeneity is indeed a negative attribute and how this information can be used to understand quality and fermentation consistency. It is anticipated that this research will enable us to develop a deeper understanding of the scientific basis of yeast population variation under stressful but non-lethal conditions. This project is directly relevant to the brewing industry, as well as others who employ fermentation and/or cultivation of yeast on a large scale and impinges on a number of sectors worldwide, including baking, oenology, distilling, and animal/human nutrition.

Chris Powell holds a Ph.D. degree on yeast cellular aging and fermentation performance from Oxford Brookes University, U.K. (2001). After a post-doctoral research position at the same institute investigating rapid methods for detection of contaminants in beer (2001–2004) he worked in the Research Department for Lallemand Inc., Montreal, Canada (2004–1010), ultimately occupying the positions of senior scientist in brewing research and project manager in genetic identification. In 2010 Chris moved to the University of Nottingham, where he is currently an assistant professor in yeast and fermentation. His core subject areas include yeast physiology and fermentation biotechnology, particularly related to the brewing, beverage and sustainable bioenergy sectors. Chris is the author or co-author of more than 50 publications, a member of the ASBC Journal editorial board and a regular reviewer for many other scientific journals. He has previously served as chair of the ASBC Technical Committee and has held a position on the ASBC Board.

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Examination of indirect methods for the assessment of microbial stability in packaged beer

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The brewing industry takes pride in the quality and consistency of the product produced. One risk to the product is the possibility of microbial contamination from beer spoilage organisms. To provide a high level of microbial assurance, the brewing industry relies heavily on direct measurements such as traditional microbiological techniques and advanced techniques such as PCR, ATP-bioluminescence, and DNA hybridization. While these tests provide insight as to the presence of such organisms in the product, no method produces results that communicate whether the product will spoil from its presence. Various product-specific attributes (ABV, IBU, etc.) and contaminant species-specific characteristics affect whether the contaminant organism will survive and produce spoilage. Knowing whether a product is susceptible to the specific organism present is important for all styles of beer, and this need has heightened with the expansion of cask and barrel products that are at higher risk for contamination. This work focuses on utilizing indirect measurements for the assessment of microbial stability. These methods include the use of forced aging via finished product incubation and interval analysis of key metrics to aid in quality-focused decision making. Packaged product with varying formulations (ABV of 5 to 12%, IBU of 10 to 100, and TG of 1.7 to 4.5°P) were treated with bacterial spoilage organisms (*Lactobacillus* sp.) and monitored for 21 Days. Some treatments were also treated with lab pasteurization once inoculated. The treatments were analyzed for total acid content, pH and turbidity throughout the experiment and compared to a control. Direct traditional microbial testing and PCR assessment were conducted in conjunction to provide baseline assurance of contamination level within treatments. Beer formulations that were not found to be susceptible did not display significant ($P > 0.05$) changes in acidity, pH and turbidity when compared to the control. Susceptible brands showed a significant increase ($P < 0.05$) in acidity, pH and turbidity. These susceptible brands displayed increases in titratable acidity of greater than 50% from the control. Treatment samples that were lab-pasteurized yielded fails on PCR evaluation; however, indirect and traditional microbial analyses did not produce any significant evidence of contamination of product and were not significantly different from the control. These results have shown that some brands have higher susceptibility than others and that direct measurements alone cannot identify whether a product will spoil. While all contamination is problematic, other factors beyond direct microbial results must be evaluated to identify whether the contaminant is a true quality risk to the product. When coupling indirect assessment of incubated product with known and robust control data, one can provide actionable data that aids in assessment of quality risk within the packaged product.

Joshua Adler received B.S. and M.S. degrees from Dalhousie University in Halifax, NS, Canada. Advised by Institute of Brewing and Distilling Fellow Dr. Alex Speers, his thesis work focused on utilizing novel methods for correlating miniature fermentations to industrial performance and identifying PYF in malt. Josh has worked as both a quality manager and production manager in the brewing industry. Josh is currently the quality manager at Victory Brewing Company. At Victory Josh strives to routinely produce beers of the highest quality, as well as create innovative and useful brewing research for all segments of the industry.

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Influence of high temperature exposure during transportation on beer flavor

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Beers transported overseas are frequently subjected to harsh environmental conditions that can negatively impact product quality. We investigated temperature profiles during the transportation of beer products from Japan to various foreign countries using temperature sensors and found that temperatures inside transport containers could reach approximately 50°C, which are markedly higher than those reached during domestic carriage. Furthermore, beers transported overseas often develop a stale flavor and sweet aroma. The Dalgliesh plot has been used to summarize the sensory changes, including a constant decrease in bitterness and increase in cardboard flavor and sweet taste, which may occur in beer during storage. We termed the sweet aroma that develops during beer storage and overseas transport as "aging flavor." In the present study, we attempted to identify the significant indicators for beer that is susceptible to the development of "aging flavor" during transport to find a sustainable approach for transporting beer overseas. Gas chromatography-mass spectrometry (GC-MS) analysis was used to analyze beer samples for known compounds that are thought to contribute to aging flavor, including (*E*)-2-nonenal, γ-nonalactone, dimethyltrisulfide, 3-methylthiopropionaldehyde, (*E*)-β-damascenone, ethyl 2-methylpropionate, ethyl 2-methylbutyrate, sotolon, and 3-methyl-2-butene-1-thiol. As the levels of these components were not sufficient to account for aging flavor, we next performed GC/MS–based non-targeted analysis to identify sensitive indicators for the development of aging flavor during transport overseas. In addition, we constructed a prediction model from the obtained chemical component profile and sensory score of aging flavor using projection to latent structure regression analysis. Using this approach, statistically significant components, including furfral and 5-hydroxymethylfurfural, which are known indicators of oxidation-induced beer flavor deterioration, were selected. As sulfur dioxide (SO_2) blocks the formation of aldehydes and ketones, thereby improving flavor stability during beer storage, we stored beers prepared with elevated levels of SO_2 at 25°C, 37°C, and 50°C to induce the formation of aging flavor. The presence of SO_2 resulted in a significant reduction in aging flavor generation at not only 25°C and 37°C, but also at 50°C. These results indicate that increasing the SO_2 level in beer is a potentially effective method for preventing the development of aging flavor during product transportation overseas.

Tomoko Koyano received a master's degree in biological sciences from the Tokyo University of Science, Japan, in 2013 and joined Asahi Breweries Ltd. She has been working on flavor analysis in the Department of Brewing and Flavor Technology of Research Laboratories for Alcohol Beverages.

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Detection of foam-negative lubricants on can lids by gas chromatography/mass spectrometry

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It is believed that a stable foam layer on the surface of poured beer slows the release of volatile flavors to the atmosphere, enhancing sensory evaluation. Additionally, the presence of healthy beer foam is considered to be both aesthetically pleasing and serves as a visual indicator that a beer has been well crafted. Discussions with fellow brewers uncovered similar observations that the foam stability of their bottled products was superior to their canned products. As a result of the observation that bottled products were consistently demonstrating superior head retention compared to their canned counterparts, even when the same batch was packaged in both formats, we sought to determine the underlying cause of weakened head retention in cans and develop a method by which other breweries could solve similar issues. Head retention was observed during sensory evaluation of heat-forced samples. Four bottles or cans from each packaging run were stored at 30°C, and head retention was observed in each of the four subsequent weeks. To identify compounds present on foam-negative and foam-neutral can lids, lids sampled from four sleeves by two manufacturers were rinsed with methanol followed by toluene. The resulting solution was analyzed using gas chromatography/mass spectrometry (GC/MS). Varying amounts of clear, colorless lubricant were discovered on the beer-contacting surfaces of the can lids observed to negatively impact beer foam. Lubricant was not detected on control can lids obtained from a second manufacturer, and the absence of lubricant correlated with improved beer foam. Butyl stearate and butyl palmitate were identified in the solvent solutions, collected after rinsing the suspect lids, and absent in control solutions of both methanol and toluene. While butyl stearate was found at up to 0.15 mg per can lid, butyl palmitate was found at levels up to 0.12 mg per can lid. These results outline a valuable method for identifying foam-negative lubricants added during can lid manufacturing that can inform brewers' selection of packaging materials suppliers.

Benjamin Schottle studied biochemical engineering at the University of Western Ontario and has worked in the craft brewing industry since 1994. He currently works in the quality and research lab at Phillips Brewing & Malting Co.

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A comprehensive evaluation of the nonvolatile chemistry affecting the bitterness intensity of highly hopped beers

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The range of different nonvolatile constituents extracted from hops in highly hopped beers suggests that iso-alpha-acids may not be the sole contributor to bitterness of beer. This presentation presents results from the second phase of a research project focused on examining factors within the beer matrix that influence sensory bitterness perception in highly hopped beers. Over 130 commercial beers were evaluated using a combination of sensory and instrumental techniques. Chemical analysis consisted of the BU, hop acids via HPLC, total polyphenols via spectrophotometry, and alcohol content plus real extract via an Alcolyzer (ASBC Methods Beer 23a, 23e, 35, 4g). Sensory analysis was conducted in two phases. Phase one focused on evaluating a large number of commercial beers with a large (19 member) trained sensory panel. One sensory replication was completed with all beers, and three replications were completed with two beers serving as internal standards. Phase two focused on evaluating a smaller number of beers (30) with a smaller (10 member) trained sensory panel. Three sensory replications were completed with all thirty beers. Of the 30 beers, 13 of the beers evaluated in phase two were also evaluated in phase one to compare and anchor the two data sets. The overall bitterness intensity of the beers was rated using a 0–20 scale. This study confirmed the inadequacy of total iso-alpha-acid content as a complete measure of beer bitterness, and resulted in the proposal of a new model to predict sensory bitterness. This model reveals the drivers of sensory bitterness and is an improvement on the traditional bitterness unit for assessing total bitterness using all of the bitter compounds found in beer. BU prediction was also modeled. Both models revealed the importance of oxidized hop acids as drivers of both sensory bitterness and the BU measurement.

Christina Hahn is a graduate student at Oregon State University (OSU) pursuing a master's degree as a member of Dr. Thomas Shellhammer's Brewing Science Laboratory. Her research focuses on the sensory perception of beer flavor and its components. Christina graduated with a B.S. degree in food science and technology from OSU in 2015. During her time as an undergraduate student she was the lead brewer for OSU's pilot research brewery. In addition to brewing at OSU she has interned for Boston Beer Company, Deschutes Brewery, and Beam Suntory.

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The impact of extracellular long-chain free fatty acids on the aroma profile of a gluten-free barley malt beer produced by means of endogenous maltpeptidases

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A gluten-free beer (<10 ppm) intended for patients suffering from celiac disease was produced from gluten-containing barley malt wort using an enzyme-enriched malt extract. Yet, the aroma profile of such beer is unknown. The results showed the treatment had a massive impact on the aroma profile concerning absence of esters such as 3-methyl-butylacetate (–93%), 2-methybutylacetate (n.d.), ethyl-hexanoate (–66%) and ethyl-acetate (–50%) compared to the reference. A reduced content of esters can be related to long-chain free fatty acids (LCFFA). The analysis of LCFFA in wort showed a significant increase in hexadecanoic acid (56 µg/g = gluten-free-wort, 2 µg/g = reference) and linoleic acid (36.5 µg/g, n.d.). The beers were analyzed further for their aging components, and analysis indicated increased amounts of heating, e.g., furfural (15.92 µg/L, 7.87 µg/L), and aging indicators, e.g., phenyl acetaldehyde (68 µg/L, 29 µg/L), although the values were below the odor threshold. GC-O/MS following a descriptive profile test showed the attribute honey was significantly increased. To clarify the findings conventional barley malt worts were spiked with hexadecanoic acid, linoleic acid and a mixture thereof, in which a significant decrease of all esters concomitant with a honey-like aroma was determined. Here, the aging aroma component analysis showed no significant difference. Through adjustment of ester content equal to the reference, the spiked beers were rated as having less honey aroma. The results show aging components are sensed more strongly in the absence of esters and, therefore, by reducing LCFFA concentrations of gluten-free wort the aroma of the resulting beer could be improved.

Roland Kerpes studied brewing science and beverage technology at the Technische Universität München (TUM). He finished his diploma thesis on the impact of unmalted oats on the quality and processability of mashes, worts, and beers at University College Cork (UCC), Ireland, in 2011 (Prof. Elke Arendt). Since 2011 he has been working on the development of a gluten-free beer using peptidase-enriched malts at the Institute of Brewing and Beverage Technology (BGT/TUM, Prof. Thomas Becker) in the Beverage and Cereal Biotechnology research group, where he's also assistant group leader. This project (AIF 16971 N) is founded by the FEI (Research Association of the German Food Industry).

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Effect of aroma on *kire* of beer

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Consumers use a variety of terms to describe beer flavors. In particular, the terms "body" and "*kire*" (the Japanese word for crispness or smoothness) are important attributes of good beer in the Japanese market. Although an internationally standardized definition of body has been established, no consensus has been reached on a definition for *kire*. At present, *kire* is generally defined in Japan as the difference in flavor between the first and last mouthfeel, and desirable *kire* leaves no residue or unpleasant flavors after drinking. In a previous study, we analyzed 14 brands of beer produced by major breweries in Japan, using gas chromatography with flame-ionization detection (GC-FID), high-performance liquid chromatography (HPLC) and spectrophotometry. In addition, to obtain quantitative data on the body and *kire* of each brand, analytical descriptive sensory testing was performed by a trained panel. Partial least squares regression analysis was conducted on the chemical and sensory data, and the results indicated that both taste and aromatic compounds affect the *kire* of beer, whereas taste compounds have a strong effect on the body of beer, and are important for the determination of body. It is well known that aroma has a strong influence on the quality and flavor of food. Therefore, the objective of this study was to elucidate the effect of aroma on the *kire* of beer. Samples of three kinds of beer, specifically the beer with the highest *kire* score and two beers with significantly weaker *kire* scores in the previous study, were used in the present study. Aroma was compared among the samples using the retronasal flavor impression screening system. In addition, the same trained panel performed sensory evaluations of the three kinds of beer. The results confirmed that beers with weaker *kire* had significantly higher levels of ethyl esters, acetates, and linalool aroma, and that these compounds significantly suppressed sensory evaluations of *kire*. Interestingly, the drinking temperature of the beer had a small effect on aroma of fusel alcohols, whereas aroma from the esters noted above decreased with lower temperatures. These findings suggest that aroma affects *kire* and that lowering the temperature improves *kire*.

Seiko Miyashita is an analyst in the Department of Brewing and Flavor Technology Research Laboratories for Alcohol Beverages at Asahi Breweries Ltd. She graduated from the Department of Material and Life Science in the Graduate School of Engineering at Osaka University before joining Asahi Breweries Ltd. in 2009. She has been engaged in the research and development of analytical technology since 2011, with a particular focus in the area of brewing science.

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Sense vs. analysis

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People can directly sense the appearance (color, clarity and foam) and flavor (smell, taste and mouthfeel) properties of beer. These, however, are subjective observations that differ between and within individuals and are poor in precision and accuracy. It is of interest to consider how and how well analytical methods represent human perceptions. Color can be assessed using a color comparator or a light absorbance measurement. Although the latter employs only a single wavelength or wavelength band, it gives a reasonably good agreement with perception, except for red and hazy beers. Measuring light scattering at a 90° angle gives good agreement with human perceptions of turbidity. Strongly colored samples cause underestimation of haze by humans and instruments. Foam measurements involving pouring from a container are problematic as they are influenced by carbon dioxide content and container geometry. Methods involving piercing a container remove the second effect. Methods involving degassing and then foaming up (e.g., Rudin head retention value) remove both. Taste involves 5–7 senses (sweet, sour, salty, bitter, umami, likely oleogustus and maybe starch) on the tongue. Some efforts have been made to develop an "electronic tongue," but these have not produced a good representation of the human senses. Smell (olfaction) includes many perceptions made when volatile compounds reach the olfactory epithelium. Gas chromatography (GC) has been used to measure volatile compounds, but no known GC detector even approximates the response of the human nose. Using an actual nose, as in GC-olfactometry, is more successful, but laborious. Efforts have been made to develop an "electronic nose"; although an "electronic nose" produces a pattern of responses like the nose, it does not produce comparable results. Efforts have been made to develop sensors for some of the chemesthetic (mouthfeel) sensations. Simple temperature measurements should work well for the physical hot and cold sensations, but not those produced by substances such as capsaicin or menthol. A sensor has been reported for astringency. Smoothness is, at least, to some extent the lack of astringency.

Karl Siebert received a Ph.D. degree in biochemistry from Penn State in 1970. He then joined the Stroh Brewery Company in Detroit, MI, where he spent 18 years and held positions ranging from research associate to director of research. In 1990, he joined Cornell University as professor of biochemistry in the Department of Food Science, where he continued to work on beverages, particularly beer, until he retired in 2015. He received two MBAA Presidential Awards, and with his colleague, Penny Lynn, received the Eric Kneen Memorial Award (for the best paper in the Journal of the ASBC in the prior year) three times. He received the ASBC Award of Distinction in 1999 and the MBAA Award of Merit in 2011. Karl is active as a consultant in beverage technology and chemometrics.

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Reliable scale up/scale down in process development—New possibilities to close the gap between lab, pilot brewery, and industrial scale

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Process and product development usually start on a small scale, and often the transfer to a large industrial scale can prove difficult, potentially leading to unexpected results. Large negative influences are seen at this scale due, for example, to altered surface/volume ratios or oxygen uptake. This can lead to additional undesired by-products, unstable processes and ultimately additional costs

for the recipe transfer from the lab scale to the industrial scale. Starting with general strategies for reliable scale-up methods, the design of a new brewing system was established. The target was to find a solution on a nano-brewing scale (only a few liters of cast-out wort) with a reproducible production. Additionally, this system is fully automated to eliminate the influence of the operator and produce a standard and consistent wort quality. Based on this consistent wort quality the nano-brewery can be used for raw material checks, such as lauter performance at the very early stages of barley breeding. In terms of product development, this system allows for rapid determination of the impacts of different grist loads and raw material ratios, not only on a small scale, but with reliable results that are comparable to the industrial processes that will later be implemented. Furthermore, in addition to raw material analysis and recipe development, the capacity of this system for early testing of process development was also a main target of its development. After the engineering and construction phase of this equipment, the next stage was the development of the automization, before finally the process parameters were optimized for the reliable scale-up functionality of this nano-brewery system.

Jan Biering apprenticed at Kulmbacher Brauerei Germany (1995–1997); studied biotechnology/brewing science at TU Berlin (1997–2003); was plant manager at Schlossbrauerei Schwarzbach (2003–2011); and since 2012 has been a scientific assistant and consultant at VLB Berlin.

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In-process sensory and beer flavor stability

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Beer flavor is not static; it is in a constant state of change requiring sensory analysis at each stage. Therefore, aligning pre- with post-production best sensory practices will ensure high quality and stability across the market. This study describes the sensory evaluation of seven brands in three seasons, represented by nine batches sensory analyzed at critical control points in their production (incoming water, brewhouse water, fermenting beer, conditioned beer, filtered beer, beer in bright tank, deaerated water, CO_2, O_2, N_2 and filters). In total, 2,765 samples have been tasted by a professional in-process panel. The results will highlight the range and intensity of dominant off-flavors in the production of each brand. The findings will then be used to advise the producer about prevention steps needed in earlier stages of production and maximize freshness, drinkability and product stability. Tasters have been trained and validated on 28 GMP Flavor Standards that are used globally by professional in-process panels within the beer industry. The project aims to improve understanding the origins of beer aging non-conformance in different stages of production, comparing tasting with instrumental data, monitoring and preventing faults and recalls. The study results are considered to be suitable to monitor beer flavor stability.

Boris Gadzov has been director of global sensory management at FlavorActiV since 2009. Boris began as a global sensory manger, professional trainer and adviser in brand equity, product quality, insight/innovation and taster management. Boris has visited over 200 breweries worldwide, and his significant language skills have helped develop business overseas and provide global beverage and multi-language support to FlavorActiV's customers. Before Boris joined FlavorActiV he earned a Ph.D. degree in food molecular microbiology from the University of Vienna.

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External risks to beer flavor quality

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The flavor quality of beer made from high-quality ingredients and processed using good-quality brewery equipment by competent brewers can be damaged in a number of ways. A particular class of flavor defects arises from sources external to the brewing process, rather than resulting from poor control of the beer production process. Such flavor defects can originate in malt, adjuncts, water, hops, yeast, processing aids, filter aids, process gases, and packaging materials. In addition, certain flavors, such as those associated with haloanisoles and halophenols, can contaminate beer with good flavor quality when transported in certain types of containers and stored in the market. In this paper we will review the types of flavors that can damage the quality of different types of commercial beers, discuss their origins, and present case studies to demonstrate best practices in the management and resolution of such problems. The impact of such flavor defects on consumer perception and liking of affected beer will also be discussed.

Amaey J. Mundkur is the business development manager at Cara Technology Limited, a specialist in beer taste panel development and yeast supply to the global brewing industry. Amaey has advised many companies on their sensory evaluation programs and has trained tasters in breweries in Europe, Asia, and North America. He has an M.S. degree in brewing and distilling from Heriot-Watt University and is a certified Cicerone™. As well as being a member of several professional organizations, Amaey has recently been chosen as a judge for the World Beer Cup and Great American Beer Festival.

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Simplify QAQC analyses and decision making with open source software

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With the recent boom in craft beer, many craft breweries cannot afford the cost of automated QAQC software, without which tracking trends in big data sets can become complicated. This presentation will introduce R and associated free software as a QAQC tool for breweries. R, and Rstudio, are both open source software that are free to download and use with no monthly fee, no recurring costs, and no advertisements. R is one of the fastest growing programming and statistical languages, and is used across many industries because it is free and highly versatile. Learning a programming language can be daunting, but R's open-source nature has resulted in an incredibly helpful community with numerous blogs, forums, and channels that answer questions both simple and complex. Here, applications for R in a brewery will be reviewed (e.g., month to date reports, fermentation tracking), and a template will be provided for R novices to quickly adapt current Excel files to perform some basic statistical analyses with minimal adjustments. The template presented was developed to facilitate QAQC efforts to optimize brewhouse efficiency, but the template and analyses described can be generalized to hop trials, mash temperature adjustments, and many other recipe and process changes. As a technical example, the data presented here illustrate how this software facilitated brewhouse optimization trials, in which we achieved a 5% grain reduction and faster lauter times simply by altering the allocation of liquor during mash in and sparging. The emphasis here, however, is how using R aided our ability to plan, execute, and successfully analyze and validate our adjustments, and how one simple script can be used for numerous types of experiments. Decision making can be a difficult process,

especially when it involves altering brewing processes or tweaking successful recipes. The goal of this presentation is to provide brewers with a template to build a reusable, personalized script to simplify common brewhouse statistical analysis and provide confidence in decision making for process improvements without the need for extensive programming experience. The open-source nature of R would mesh well with the largely cooperative nature of the brewing industry, since complex statistical processes, functions, and packages in R can be shared and reproduced. Ultimately, beer quality could be collectively elevated by fostering more transparent, scientific approaches to beer QAQC.

Drew Russey received a Ph.D. degree in biology from the University of Houston in August 2014. His dissertation focused on adaptive evolution of functional, multivariate traits resulting from natural and artificial selection. He joined Saint Arnold Brewing Company as a laboratory technician in August 2014 and was promoted to laboratory manager. This role includes aiding the QA/QC team in their statistical analyses of raw materials, product trends, and various brewhouse projects.

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A novel concentration and viability detection method for *Brettanomyces* using image cytometry

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There has been increasing interest in the recent years for utilizing *Brettanomyces* spp. in the brewing industry due to their novel flavor and aroma compounds, which are used to create complex flavors for specialty beer products. Currently, several breweries have been performing 100% *Brettanomyces* fermentation for their beverage products, such as Midnight Brett from Allagash Brewing Company. One of the challenges when working with *Brettanomyces* spp. is the formation of pseudohyphae, which can increase the difficulty for utilizing the traditional yeast enumeration method during the fermentation process. The current cell counting method involves manual counting of methylene blue-stained yeasts in a hemocytometer using light microscopy. However, the method can be time-consuming and has high operator-dependent variations. More importantly, subjectivity of what should be counted in the pseudohyphae makes enumeration of *Brettanomyces* cells extremely difficult. Therefore, it is important to develop a rapid, robust, and non-subjective method for the quantification of *Brettanomyces* spp. Numerous breweries have employed the use of automated fluorescence-based image cytometers with acridine orange (AO) and propidium iodide (PI) fluorescent stains to overcome issues from manual *Saccharomyces* counting. In this work, we demonstrate a novel cell concentration and viability detection method for *Brettanomyces* using an image cytometer (Nexcelom Bioscience, Lawrence, MA). First, the automated cell counting method was developed by measuring the yeast propagation of three yeast strains: *B. bruxellensis*, *B. clausenii*, and *B. lambicus*, where the counting results were validated against the manual counting method. Finally, two fermentation batches of *B. clausenii* and *B. lambicus* were monitored for 42 days, where cell concentration, viability, and budding/pseudohyphae percentages were measured throughout the fermentation. In the propagation experiment, *B. clausenii* took the longest to start growing, but reached the highest cell concentration on day 5 at a concentration of 7.87×10^9 cells/mL. *B. lambicus* showed the quickest propagation, requiring only 24 hr to reach its maximum cell concentration of 4.21×10^9 cells/mL. Finally, *B. bruxellensis* reached 5.78×10^9 cells/mL after 2 days, but took an additional 2 days to reach its peak cell concentration of 6.74×10^9 cells/mL. *Brettanomyces* cell viabilities were measured simultaneously. In the fermentation experiment, the two 100% *Brettanomyces* fermentations, *B. clausenii* and *B. lambicus,* exhibited two very different growth curves. The results showed that *B. clausenii* exhibited an extended lag phase of approximately 12 days before increasing substantially to ~1.7×10^8 cell/mL from day 12 to 15 during the log phase. In contrast, *B. lambicus* exhibited an extended log phase with a steady increase in cell concentration from day 3 to 14, with substantial fluctuation. The proposed novel image cytometric analysis method can provide a simple and non-subjective automated counting method for *Brettanomyces*, which can replace traditional counting methods to improve efficiency and consistency during the fermentation process.

Leo Chan currently serves as the technology R&D manager at Nexcelom Bioscience LLC, Lawrence, MA. His research involves the development of instrument and applications for the Cellometer image cytometry system for detection and analysis of yeasts used in the brewing and biofuel industries. He is a member of the Master Brewers Association of the Americas and American Society of Brewing Chemists. He received his B.S., M.S., and Ph.D. degrees in electrical and computer engineering from the University of Illinois at Urbana-Champaign (2000–2008).

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Barley fungi and their mycotoxins in beer production

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Decreased barley crop yield and quality is often the result of pathogenic fungi that originate from the contaminated seed, the wind, or the soil (e.g., from crop residues). Well-known fungal diseases of barley are powdery mildew, blotch, leaf spot, rust, stripes disease, ergot, and *Fusarium* head blight (FHB). FHB is caused by strains of several *Fusarium* species and favored by humid conditions during flowering and early stages of kernel development. *Fusarium* fungi can produce many different toxic metabolites (mycotoxins) such as trichothecenes (e.g., deoxynivalenol = DON), fumonisins, zearalenone, and enniatins. Mycotoxins are considered to be the most dangerous chronic-toxic contaminants present in the human diet. The tolerable daily intake dose (TDI) of the main *Fusarium* mycotoxins are between <0.06 and <2 µg/kg body weight. For T-2 and HT-2 for example a consumer can already exceed the total permitted daily intake dose with the consumption of one liter of beer containing 3 to 5 µg/L of the toxins. In addition, a variety of modified forms of mycotoxins occur which can lead to an underestimation of the true amount of mycotoxins in foodstuffs. In beer, glycosylated mycotoxins can be expected that can be released from the grains during the brewing process. For the malting and brewing industry it remains a challenge to produce malt and beer with the lowest possible levels of mycotoxins and their modified forms. Samples from the entire processing from grains up to the final beer were analyzed with LC-MS/MS for 18 (modified) mycotoxins. The quantitative multi-mycotoxin analysis method was optimized for liquid, solid, and mixed samples to a limit of quantification of 0.03–53 ppb, depending on the type of mycotoxin. In beers of eight different Belgian beer types produced in 2014 or 2015, rather low concentrations of mycotoxins were found, mainly DON, DON-3-glucoside (DON-3G), enniatine (ENN), and (modified) zearalenon (ZEN) metabolites. Despite these low concentrations, a probabilistic risk analysis revealed that consumers of fruit beers can be at risk for HT-2. Malting did not lead to a clear increase in mycotoxins, even not for the five experimental cases where spores of *Fusarium* strains were pitched at the beginning of the

germination of the barley and outgrowth of the fungus occurred. An incubation of milled pale malt with the same five *Fusarium* strains during four days also resulted in visual growth of the fungus, but without significant mycotoxin increases. It was concluded that mycotoxin production takes place mainly on the field, probably because during malting the fungi are not stressed by limited resources. The pilot and industrial brews, which were followed up for mycotoxin content by sampling at 11 to 13 process points, revealed that water-soluble mycotoxins like ϸzearalenol are released from the milled malt and stay present up into the final beer. The less water-soluble mycotoxins like zearalenone mainly remain in the spent grains. DON and DON-3G show intermediate behavior.

Anneleen Decloedt graduated in 2011 with an M. S. degree in biochemistry and biotechnology from Ghent University. In 2014 she was the project manager of the Beer4Dreams team that won the first and public price at the Belgian Ecotrophelia competition and the fourth price at the European competition. She successfully defended her Ph.D. in public health and food safety at the Laboratory of Chemical Analysis, Ghent University in 2015. Since January 2015 she has been working as a research fellow at the Laboratory of Biochemistry and Brewing of Ghent University and University College Ghent, regularly presenting her work in scientific papers and at international congresses.

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Rediscovery of *Lactobacillus pastorianus* Van Laer 1892, a beer spoilage *Lactobacillus* species named in honor of Louis Pasteur, and studies on its extraordinarily unique culturability

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Lactobacillus pastorianus was first described by Pasteur in 1876 and isolated by Van Laer in 1892. Therefore, *L. pastorianus* was recognized as the first beer spoilage *Lactobacillus* discovered in brewing microbiology. Mysteriously, this honorable species vanished in the brewing history and became almost forgotten. For the progress of brewing microbiology, this historic species should be rediscovered and recharacterized. A century later, one strain (*L. paracollinoides*) was found from a spoiled beer. This strain, designated as *L. paracollinoides* JCM 11969^T, initially exhibited no culturability on any culture media except for beer. The stepwise adaptation to deMan, Rogosa and Sharpe (MRS) broth, in which degassed beer as a subculture medium was progressively replaced by an increasing proportion of MRS broth in 10 point increments, finally allowed the isolation of *L. paracollinoides* JCM 11969^T. Strikingly, our taxonomic studies indicated *L. pastorianus* (Van Laer 1892) is identical to *L. paracollinoides* JCM 11969^T at the species level, on the basis of 16S rDNA sequence analysis and DNA-DNA hybridization study. This finding led us to further study of *L. paracollinoides*, focusing on its culturability on microbiological media. As a consequence, *L. paracollinoides* JCM 11969^T in a hard-to-culture state was found to grow optimally at pH 4.7 but very poorly at pH5.3. No growth was observed at pH 5.6, which is often the approximate pH value adopted by conventional culture media for beer spoilage lactic acid bacteria. Its growth was also inhibited by most of the nutrient sources typically contained in culture media, including sodium acetate, yeast extract, peptone and manganese. These characteristics were also observed with another *L. paracollinoides* strain JCM 15729 in hard-to-culture state, suggesting these are common features of this species. Furthermore *L. paracollinoides* JCM 11969^T showed a strong sensitivity even to agar, a solidifying agent widely used for culture media in primary isolation. All of these characteristics account for the unculturable nature of *L. paracollinoides*. Interestingly, the distinguishing pH-dependent growth characters and nutrient sensitivities were no longer observed for the *L. paracollinoides* strains obtained by the stepwise adaptation to MRS broth, suggesting the long-term habitation in brewing environments is responsible for the hard-to-culture state in *L. paracollinoides*. In addition, additional environmental surveys revealed the presence of 18 *L. paracollinoides* strains, all of which exhibited no growth on conventional culture media. Taken together, these findings indicate that the species *L. paracollinoides* is common and ubiquitous in brewing environments, but extremely difficult to culture upon primary isolation from their natural environments. The indication that *L. paracollinoides* and *L. pastorianus* (Van Laer 1892) are synonymous explains why this historic species has been hidden for so many decades despite its ubiquitous distribution in brewing environments. This presentation summarizes 27 years of our studies on their extraordinarily unique culturability and provides useful insights for brewing microbiologists in developing a comprehensive QC culture medium for beer spoilage bacteria.

Koji Suzuki joined Asahi Breweries, Ltd. in 1992 and functions as a manager in the Quality Control Center. He received a Ph.D. degree from Tokyo University in 2004 and two awards from the Brewing Society of Japan in 2007 and 2009 for his work concerning beer spoilage lactic acid bacteria. In 2011, he also received a technology award from the Japanese Society for Bioscience, Biotechnology, and Agrochemistry. At present, he lectures on fermentation food science at Meiji University and serves on an editorial board of the Journal of the Institute of Brewing. He has authored many original and review papers, as well as several book chapters, such as those published by Elsevier Science and Woodhead. He is currently a vice chair of the BCOJ Analysis Committee and also serves as a member of the Industry-Government-Academia Collaboration Committee in the Japanese Society for Food Science and Technology.

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Worse than we thought: A *Megasphaera cerevisiae* isolate is able to spoil full-strength beer

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Strictly anaerobic beer spoiling bacteria are generally believed to have gained a foothold in the industry as a result of technological advances in anaerobic filling in the 1980s. Among these organisms, *Megasphaera cerevisiae* produces particularly offensive off-flavors, including butyric acid, but no literature exists to demonstrate its growth in beer containing greater than 4% ethanol. This study explores the genomic and physiological traits underpinning the ability of a canning line isolate of *M. cerevisiae* to grow in beer containing up to 5% ethanol—the first known case of this organism documented to grow above 4% ethanol. Using polymerase chain reaction (PCR) and specialized microbiological methods, *M. cerevisiae* strain NSB1 was identified and isolated from the underlid CO_2 injector of a brewery canning line. Whole genome sequencing was carried out, and data were analyzed against the only previously sequenced *M. cerevisiae* strain, which is not known to grow above 4% ethanol. Initial isolation of the bacteria was carried out on Wallerstein differential agar. Growth experiments were carried out in beer containing varying ethanol concentrations and pH levels, as well as in modified de Man, Rogosa and Sharpe media containing ethanol and adjusted to pH 4.6. All cultures were grown and maintained anaerobically. NSB1 demonstrated strong growth in beer containing up to

5% ethanol above pH 4.5, accompanied by copious off-flavor production. Genomic sequencing of NSB1 indicated a diverse set of potential mechanisms by which the strain thrives in elevated ethanol concentrations, including genes encoding a variety of efflux pumps and alcohol dehydrogenase not present in the previously sequenced reference strain that has not demonstrated growth above 4% ethanol. In addition, the presence of several sets of glycerol degradation pathways suggests a previously unidentified energy source for *M. cerevisiae* during growth in beer. Eradication of the biofilm housing the bacteria was carried out using sequential applications of hot sodium hydroxide, nitric acid and acidic hydrogen peroxide. Using PCR of surface swabs and packaged products, the elimination of the bacterial population was confirmed. These results demonstrate the urgency for increased vigilance toward these bacteria, which contrary to conventional wisdom may be capable of growth in regular strength beer, and suggest a need for improved tools for the detection and identification of bacteria requiring specialized growth conditions.

Euan Thomson manages the Quality, Research, and Malting Departments at Phillips Brewing & Malting Co. in Victoria, Canada. During his three years at the brewery, he has introduced new methods for the molecular detection of various bacteria and wild yeast over a range of brewery process steps and established research partnerships with local scientists to explore yeast physiology and epigenetics, barley polyphenols, packaging material contaminants, aging markers in whisky, methods for hop oil emulsification, and chemical analysis methods for beer and raw materials. He has a Ph.D. degree in microbiology and spends his free time exploring the Vancouver Island backcountry, playing music and helping to build the island community.

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Dry hopping and stirring pellets increases vicinal diketones and lowers apparent extract

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Dry-hopping beer is desirable to isolate the herbaceous, green, fresh hop aroma associated with American India pale ales. Before dry-hopping and after a beer is fully attenuated, most amino acids present in the wort have been assimilated by yeast for the purpose of making proteins. In a nutrient-depleted environment yeast may be forced to autonomously produce amino acids. One such amino acid, valine, when biosynthesized relates to the production of diacetyl, a vicinal diketone (VDK). Heightened concentrations of diacetyl, 40–70 ppb, have been observed in dry-hopped beers at 68–70°F after rousing the yeast from the bottom of the vessel. In addition, the apparent attenuation decreases 0.1°P/day, while the cells in suspension increase. These data support the hypothesis that secondary fermentation is occurring in agitated and dry-hopped beers. Lowering the temperature of the fermentation to 60°F before dry-hopping promotes yeast flocculation and, after rousing the pellets, subdues the increase in VDK concentration, while reducing the decline in the apparent extract. Interestingly post–dry-hopping, we consistently observe an increase in gravity of approximately 0.1–0.2°P, regardless of the temperature at the time of dry-hopping. Understanding the enzymatic activity would elucidate the mechanism of the hypothesized secondary fermentation. With increased hop loads and 18% more craft breweries from 2014 to 2015 that do not have the lab power to study secondary fermentation, understanding the effects of dry-hopping will allow for greater process control and the ability to increase accuracy in projected production schedules.

Andrea Baillo is the former QA manager of Maui Brewing and is currently the QA manager of Melvin Brewing.

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Sensory directed mixture study of beers dry-hopped with Cascade, Centennial, and Chinook

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American craft beer style/flavor is often driven by the unique qualities of American hops. Cascade, Chinook, and Centennial hops are prominently used singly and in blends by brewers. A sensory-directed mixture study was performed to understand the contribution that each of these hops makes to beer flavor. Fifteen beers were prepared by dry-hopping a common base beer with different blends of the whole cone hops from the three individual hop cultivars. The treatments were evaluated by trained panelists using descriptive analysis, where the response variables encompassed the sensory attributes describing unique aromatic features of the three hops, (i.e., citrus, tropical/fruity, tropical/catty, herbal). Using these outputs, response-surface diagrams were produced illustrating the sensory contributions of each individual cultivar, as well as mixtures of the cultivars, on a per attribute basis. These response diagrams can be used to select combinations of the three hops that provide similar or dissimilar overall flavor. Brewers, growers, and suppliers will benefit from these response diagrams when faced with varying availability of individual cultivars in selecting hops.

Thomas Shellhammer is the Nor'Wester Endowed Professor of Fermentation Science in the Department of Food Science and Technology at Oregon State University, where he leads the brewing science education and research programs. His brewing research investigates hops, beer quality and the origins of hop aroma and flavor in beer. He is a past president of the ASBC, the current president of the MBAA District Northwest, and serves on the Board of Examiners of the IBD. Thomas received his Ph.D. degree from the University of California, Davis in 1996.

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Impact of hop pellet processing in regard to flavour contribution in beers late and dry hopped with U.S. Cascade hops

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With the increasing amounts of hops in beer, especially when dry-hopping is applied, the consequences for the brewing process in a handling and also in an economic context are becoming more important. For dry-hopping, mostly normal pellets are used, containing the same components as cone hops do. The pelletization of hops offers various possibilities for enriching the alpha and oil contents of the produced pellets. Also, the choice of pellet dye offers possibilities to change pellet density. In this work we brewed a series of late- and dry-hopped beers using different grade of enrichments of U.S. Cascade hops. All beers were analyzed for hop aroma components and thoroughly tested with different sensory schemes. The results show that small changes in pelletization have a significant impact on the hop flavor in beer. The results also show how the "typical" flavor of a hop variety can change due to enrichment in pelletization. These results offer possibilities to optimize hop flavor in dry-hopped beers, to decrease beer loss due to dry-hopping and to achieve new flavor simply through different pelletization parameters.

Mark Zunkel obtained his B.S. and M.S. (Dipl.-Ing.) degrees from the Technische Universität München–Weihenstephan, Chair of Brewing and Beverage Technology. As part of his studies, he

interned at multiple breweries in the United States and Germany. His concentration was on beer and hop aroma compounds, and he compiled the Beer and Hop Flavor Databases for ASBC. In 2011, he started working as a technical manager for Joh. Barth and Sohn based in Nuremberg, Germany. After his workday is done, he is busy establishing the first craft brewery in Nuremberg.

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First wort hopping: An evaluation of its chemistry and sensory impact

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Many factors influence the bitterness of beer, and the timing of hop additions during wort boiling is one well-known factor. First, wort hopping (FWH) is a technique where hops are added to the first runnings of wort from the lauter tun before "kettle full" and before wort boiling. This method exposes the hop material to wort at lower temperatures and an elevated pH for an extended period of time. Research related to FWH is limited, and details surrounding the studies remain vague. Proponents of the technique suggest FWH produces a beer with improved bitterness qualities and use terms such as "smooth" or "harmonic" to describe its effects. Research at the Oregon State University Pilot Brewery examined these claims by preparing two beers with the same mass of hops but varied in the timing of the hop addition. The FWH beer was prepared by adding the hops to the kettle prior to wort collection, while the reference beer was prepared by adding the hops to the wort at the start of boil. This comparison was carried out on a pilot scale and repeated on a commercial scale to produce two sets of beers: the former with a target BU of 35 and the later with a target BU of 20. Chemical analysis revealed negligible differences between the treatment and reference for both sets of beers, with one exception—the total polyphenol content (TPP). The FWH beer was slightly higher in TPP compared to the reference beer, suggesting that FWH technique may influence the extraction of polyphenolic material. However, sensory discrimination testing showed no difference between the reference and FWH beers. These results suggest that while the FWH technique has a minor influence on polyphenol extraction, it has a negligible influence on the sensory properties of the resultant beer.

Christina Hahn is a graduate student at Oregon State University (OSU) pursuing a master's degree as a member of Dr. Thomas Shellhammer's Brewing Science Laboratory. Her research focuses on the sensory perception of beer flavor and its components. Christina graduated with a B.S. degree in food science and technology from OSU in 2015. During her time as an undergraduate student she was the lead brewer for OSU's pilot research brewery. In addition to brewing at OSU she has interned for Boston Beer Company, Deschutes Brewery, and Beam Suntory.

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Investigating enzymatic power of hops

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With the increasing trend of greater dry-hopping rates, the impact hop compounds have on beer flavor and beer quality becomes more important, but it is not entirely understood. Experiments carried out at OSU suggest that residual enzymatic power of hops can be transferred to dry-hopped beer and, in turn, influence the composition of its fermentable and nonfermentable carbohydrates. Fully attenuated and packaged American lager beer was dry-hopped at a rate of 10 g/L with pelletized Cascade hops, dosed with 1 million cells/mL of ale yeast, and incubated at 20°C. Real extract of the treated beer declined significantly within several days, with a drop of 1°P RE after 5 days, which when fermented is equivalent to the production of an additional 2.5% (v/v) of CO_2 and an additional 0.5% (v/v) of alcohol. Further analysis of the carbohydrate profile via HPLC of dry-hopped beer in a yeast-free beer stabilized with sodium azide indicated an increase in appreciable levels of glucose and maltose in beer incubated with pelletized Cascade hops. Over a period of 1 week, glucose steadily increased to 15-fold its original concentration, and maltose increased by threefold compared to an unhopped control. The residual enzymatic activity of hops in beers containing active yeast may result in excessive build-up of CO_2 in packaged beer, which represents a safety hazard, along with alcohol contents that are out of specification.

Kaylyn Kirkpatrick is a graduate student in the Oregon State University Brewing Science Laboratory under the mentorship of Dr. Thomas Shellhammer. She obtained her B.S. degree in biochemistry from Colorado State University in 2013 and was awarded a Diploma in Brewing through the Institute of Brewing & Distilling in 2016. Her research focuses on the effects of hop and yeast interactions on beer fermentation and flavor.

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Kinetic modeling of terpenes in packaged beers

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In modern brewing, it is well understood that the aromatic compounds in dry-hopped beer are not in equilibrium and decrease rapidly. However, it is still unclear as to how and to what extent dry-hopped beer aroma declines. The essential oil fraction, making up only 1% of a dried hop cone, is responsible for the "raw" or "green-hopped" aroma. The most prevalent compounds in "green hop" aroma are monoterpenes, monoterpene alcohols, and sulfur compounds. While "green hop" aromas are highly desired by consumers in the modern beer market, the compounds that provide these aromas are also inherently unstable. This study describes the dynamic decrease of monoterpenes, monoterpene alcohols, and sulfur compounds as dry-hopped beer ages. Beer samples aged for up to 8 weeks were degassed and prepared according to internal methods for SPME utilizing a 65 µm, PMDS/DVB fiber. Numerous runs and replicates were performed to build a first-order kinetic model of hop aroma decline employing non-linear regression. This model can help to serve as a "best practice" guideline for brewers seeking to understand the rate of hop aroma decline and how this can help inform shelf-life strategies.

Margaux Huismann graduated with a B.S. degree in microbiology from the University of Wisconsin-La Crosse in 2014. She went on to complete her M.S. degree in brewing and distilling at Heriot-Watt University at the International Centre for Brewing and Distilling. In her master's project, Margaux worked with a team of ICBD master's students to create Edinburgh Gin's Seaside gin. She is now a second-year Ph.D. student at the ICBD, supervised by Dawn Maskell and Alex Speers, studying "The Physical-Chemical Evolution of Dry Hopped Beers" with BrewDog.

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Identification of hop varieties and growing region by gas chromatography-sulfur chemiluminescence

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In the ever-evolving world of hops, the constant introduction of both new and novel varieties can lead to uncertainty concerning

the true origins of a sample being presented. There are a handful of varieties that while comprised of the same rootstock possess different brand names based upon who grew them and where. The potential for overlap between new and existing varieties has led to a need for reliable hop characterization methods. While researching techniques for hop characterization through chemical analysis, the established publications only focused on the terpenes in essential oils. These publications also focused on the direct comparison of chromatographic results against that of other samples to determine varietal differences. In recent years the importance of the sulfur compounds, in the form of polyfunctional thiols, has become apparent. Through the early adoption of this mindset we identified a trend in our sulfur chemiluminescence data. The observed trend led to the realization that thiol compounds can be used as a fingerprint for both variety and growing region. We were able to create an initial database from samples in our inventory by converting the chromatographic data to ratios based on a common peak found in all varieties. With this database, we established the viability of our methodology and expanded it to include other varieties and regions. This ratiometric scrutiny allows for the validation of variety and growing region through impartial scientific analysis.

Ryan Foster is the lab director at Virgil Gamache Farms in Toppenish, WA. He has spent the last four years working in both flavor and fragrance and the hop industry. His work areas have focused on organic synthesis, analytical analysis, and product assessment. While at Virgil Gamache Farms he has focused on verifying current in-house methods and developing new techniques to be used in the analysis of hop cones. He is a member of ACS, ASBC, and MBAA. Ryan completed his B.S. degree at Northern Michigan University.

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The language of hops—Practical applications of a tasting scheme for hop flavor

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The many new hop varieties emerging every year, which are strongly connected to developments in the craft brewing scene, and the significantly larger hop dosages have caused the need for a more detailed and comprehensive way of describing hop flavors in hops, hop products, and the final beer. This led to the introduction and design of a tasting form that can be an industry-wide approach to speaking the same language about hops. This poster shows more details about this new hop flavor tasting form and descriptions, including a new flavor categorization. It also explains how to best train, implement and apply this way of flavor description into your business—be it a hop grower, brewer, beer judge or simply an enthusiast about hops and beer.

Mark Zunkel obtained his B.S. and M.S. (Dipl.-Ing.) degrees from the Technische Universität München–Weihenstephan, Chair of Brewing and Beverage Technology. As part of his studies, he interned at multiple breweries in the United States and Germany. His concentration was on beer and hop aroma compounds, and he compiled the Beer and Hop Flavor Databases for ASBC. In 2011, he started working as a technical manager for Joh. Barth and Sohn based in Nuremberg, Germany. After his workday is done, he is busy establishing the first craft brewery in Nuremberg.

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Quantitative lateral flow assays for rapid determination of deoxynivalenol in barley and malt

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The fungal pathogen *Fusarium head blight* (FHB) affects barley and wheat causing loss of yield, kernel damage and negatively affects the quality of finished malt and beer. The fungal species *Fusarium graminearum* thrives in malting conditions and produces toxic bi-products that are able to survive the malting and brewing process. Deoxynivalenol (DON), part of the tricothecene mycotoxin family, is a toxin most commonly produced by the fungi *Fusarium*. DON can been detected in kernels that that do not show FHB symptoms. The accurate measurement of the levels of DON is an important critical control point in the selection of barley for malting and in finished malt. Rapid methods are required for screening grain samples at intake for selection and segregation. Typically commercial kits employing on Enzyme Linked Immunosorbent Assay (ELISA) are used for this purpose, and have been adopted as official methods in the industry. More recently a class of rapid test kits based on an immunochromatographic principle, also called Lateral Flow Aasays (LFA) have become available offering rapid and sensitive detection of DON in a variety of matrices. In this study, two different commercially available lateral flow assay kits, Charm ROSA DONQ2 and Neogen Reveal Q+ were used to quantify DON levels in samples of un-malted and malted barley. Results were compared with both traditional ELISA and high performance liquid chromatography methods. Analysis of Variance (ANOVA) was used to determine whether the method means generated can be considered as equal. The LFA results were well correlated with the reference methods over the range of activity normally encountered. The repeatability of the LFA was found to be similar to ELISA with improvement in speed and ease of use. The immuno-assays are very powerful screening tools to assess a large number of samples in a rapid timeframe with a minimum of effort, avoiding costly labor or expensive lab equipment. These kits were found to be well suited for screening and possess the sensitivity to adequately screen un-malted grain samples and differentiate positive from negative samples. It is advisable to analyze samples flagged by rapid methods as positive using chromatography for precise quantification.

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Rapid automated method to measure alpha-amylase activity in malt

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Alpha-amylase is responsible for rapid degradation of starch during mashing and promotes fast conversion. Alpha-amylase is synthesized during the malting process and is influenced by variety and the degree of modification. Low levels of alpha-amylase can lead to long conversion times and poor extract yields in the brewery. In modern malt quality laboratories, alpha-amylase activity is measured by monitoring the color change of the reaction of a buffered extract of malt with a dextrinized starch substrate and iodine using segmented flow analysis to increase sample throughput; however, these systems are expensive and require large amounts of reagents. In this paper, a fast, automated alpha-amylase analysis method for Thermo Scientific™ Gallery™ discrete analyzers is presented. The method is adapted from chemistries described in ASBC method Malt 7-A and 7-C using fixed

reaction time and temperature. Reactions are performed at 37°C and a photometric endpoint measurement at 660 nm. A method comparison study was performed by analyzing a series of malt samples using a range of alpha-amylase. The comparison included the automated method and ASBC Malt-7C as a reference method. The novel method was well correlated with the reference method over the range of activity normally encountered. The repeatability and reproducibility of the new method was also determined. Benefits include automation of sample dispensing, standardized analysis conditions and use of microliter volumes of reagents that reduces both analysis time and costs without compromising method performance. Discrete analyzer technology enables multiple samples and parameters to be analyzed simultaneously.

Liisa Otama earned both B.S. and M.S. degrees in analytical chemistry from the University of Helsinki, Finland. She joined Thermo Fisher Scientific in 2008 and has held several positions ranging from process engineering to R&D. In her current role as a product manager for discrete analyzer reagents and applications, she is responsible for identifying new customer needs, as well maintaining and continuously improving the existing product portfolio. Her expertise is highly customer-focused and includes evaluating industrial product feedback and addressing inquiries, in addition to supporting customer training.

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Development of a new highly sensitive method for predicting gushing potentials in beer products

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"Beer gushing" is an undesirable phenomenon that occurs when beer and foam forcefully erupt from a beer bottle immediately after it is opened. Since this is a quality issue easily recognized by customers, there is the danger of serious damage to the company's brand if such products are allowed on the market. Multiple causes of gushing are known, but the most frequent is contaminated malt, defined as a "primary gushing factor," and thus discriminated from "secondary gushing factors." At Asahi Breweries, malt crops that induce a gushing phenomenon are called "gushing malt." A widely accepted method for predicting gushing potentials in malt samples is the modified Carlsberg method. This method is useful for evaluating malt samples themselves for the presence of gushing potentials, but it does not reveal any other gushing factors that may arise during beer manufacturing processes. In addition, the modified Carlsberg method sometimes lacks sufficient sensitivities, leading to false negative results for malt samples that exhibit undetectable gushing potentials by this approach. Under these backgrounds, Asahi Breweries, Ltd. has developed a new method for predicting malt gushing potentials, which entails a small-scale (200 mL) trial, mimicking the actual beer manufacturing process. As a consequence, this new method was shown to detect not only the gushing determinants present in malt itself, but also the gushing risks that become apparent during the beer manufacturing process. The comparative analysis also demonstrated that Asahi's method is three times as sensitive as the modified Carlsberg method. In the course of examining over 100 malt crops in the preliminary testing stage, it was further found that some types of gushing malt crops exhibit high sensitivities to the metal iron released from the diatomaceous earth commonly used in the beer manufacturing process. As a consequence, these malt crops were shown to induce gushing when the iron concentration is above a certain level. Therefore, to predict the risk of iron-sensitive gushing malt crops, Asahi developed a modified method, in which the iron concentration is adjusted to the same level as that of beer products, using a specially blended diatomaceous earth for our small-scale predictive model. This modified method was shown to detect malt crops that exhibit iron-dependent gushing potentials. Moreover, the applications of our new method correctly identified the gushing potentials of malt crops that were affected by molds due to poor weather. Some of the examples included the 2007 and 2013 crops in Europe and North American crops produced since 2014. Taken collectively, our new method is useful for the highly sensitive and comprehensive detection of malt crops with gushing potentials. Through the monitoring for each lot of malt crops, Asahi Breweries has successfully introduced a system that prevents the use of malt that may cause gushing in beer manufacturing.

Miyuki Takahashi joined Asahi Breweries, Ltd. in 1997. Since 2002, she has been responsible for performing the analysis of alcoholic products and their raw materials to assure product quality. She has also been involved in developing new analytical methods and improving their reliability. She is currently a leader of the analytical group for alcoholic beverages and raw materials.

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Statistically significant difference between the aroma profiles of beer brewed from sorghum and barley malt

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There is currently an increase in foodstuffs that are gluten-free, including beer. Beer produced from gluten-free grains has a distinct flavor that differs greatly from beer produced from gluten-containing grains. The chemical difference between beers made from these two different grain sources has been explored, and some key differences have been identified. It is the goal of this project to look at the chemical difference within the aroma between beers made from malt sources containing gluten (barley) and malt without gluten (sorghum) for compounds with statistically different concentrations. A total of 12 (6 barley and 6 sorghum) small-batch beers were made from malt extract. The aroma profile was sampled using SPME with chemical separation and identification and quantification using GCMS.

Drew Budner earned a B.S. degree in chemistry from Adams State University and a Ph.D. degree in analytical chemistry from South Dakota State University. He taught at Whitworth University from 2006 to 2013 and Coastal Carolina University from 2013 to the present. His research group focuses on creating a chemical profile of beer.

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Analysis of fermentable carbohydrates using high-performance liquid chromatography in gluten and gluten-free beer

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The purpose of this study was to develop a consistent, reliable method to detect and quantify carbohydrates, such as glucose and maltose, throughout the fermentation process of gluten and gluten-free beer. A precolumn derivitization procedure with 1-phenyl-3-methyl-5-pyrazolone (PMP) followed by high-performance liquid chromatography (HPLC) was used to separate and quantify the carbohydrates during the fermentation process over a period of 2 weeks. Determining the composition of glucose and maltose over time is crucial in monitoring fermentation as well as evaluating the quality of the beer. The separation and quantification of the derivitized carbohydrates were performed using a mobile phase of acetonitrile to ammonium acetate buffer (0.1 M, pH 5.5) of 22:78 (v/v) at a flow rate of 1.5 mL/min. PMP produces strong UV absorbance at 245 nm. Both barley and sorghum brews were studied with aliquots removed and analyzed at days 3, 7, 10,

and 14 of the fermentation process. Successful separation and quantification of glucose and maltose in wort and aliquots were established using this method.

Drew Budner earned a B.S. degree in chemistry from Adams State University and a Ph.D. degree in analytical chemistry from South Dakota State University. He taught at Whitworth University from 2006 to 2013 and Coastal Carolina University from 2013 to the present. His research group focuses on creating a chemical profile of beer.

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Alcohol by rapid distillation

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Determining alcohol content accurately and precisely is essential in the brewing industry for a variety of reasons: to conform to government laws ensuring that proper taxes are paid, to confirm that the product meets label specifications, to meet quality control parameters, and to maintain consistency in products. While the NIR/density method (ASBC Beer-4 G) is quite suitable for measuring the alcohol content of beer, flavored malt beverages present a challenge. Interference with the instrument measurement can result from flavor additions. A more accurate way to measure alcohol in this type of product is standard distillation (ASBC Beer-4). Unfortunately, this method is time-consuming and labor-intensive. Due to these drawbacks, an alternative method was investigated. A rapid distillation unit was selected as the alternative for its ability to rapidly distill using the power of steam. A precision study was performed to determine repeatability and reproducibility. Three analysts distilled five different brands with alcohol levels ranging from 4.2 to 14.4%, v/v. Repeatability and reproducibility coefficients of variation for the determination of alcohol for this range were 0.05–0.23% and 0.11–0.19%, respectively. In addition, results from ASBC Beer-4 and rapid distillation were assessed using a paired *t* test for alcohol levels ranging from 3.6 to 14.4%, v/v. The *P* value = 0.30, showed that there was no statistically significant difference between the means of the data sets at a 95% confidence level.

Lacy Cloninger graduated from Southern Illinois University of Edwardsville, IL, where she earned a B.S. degree in biology, with a minor in chemistry, in 2013. In 2014, she pursued an internship with Anheuser-Busch InBev, Inc. for the North American Zone Central Laboratory. This led to her current position as a scientist within the Central Laboratory with a focus on mashing studies and optimizing brewhouse processes, as well as performing analytical assays. In her free time she enjoys spending time outdoors, camping and hiking with her husband.

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Mashing lactose into a fermentable adjunct

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Lactose, milk sugar, is commonly used in beer as a non-fermentable sugar. It is a disaccharide composed of glucose and galactose, but brewer's yeast, *Saccharomyces cerevisiae*, does not have the enzymatic ability to break the beta-1,4 bond linking the monosaccharides. A beta-galactosidase with activity against lactose has been isolated from barley; however, it rapidly loses activity at typical mash temperatures of >50°C. A modified mash profile, with a lower initial temperature, could allow this enzyme to hydrolyze lactose into glucose and galactose for utilization by *S. cerevisiae*. This would allow for the incorporation of lactose as a fermentable adjunct sugar in beer production. The objective of this study was to evaluate whether a barley mash with a step at the beta-galactosidase optimum temperature of 40°C would result in the detectable hydrolysis of added lactose. A 250 mL mash containing 65.9 g of barley meal and 25 g of lactose was stirred constantly at 40°C for 3 hr. A control mash consisting of barley meal and water, with no lactose added, was used to determine the amount of free glucose in the grain or glucose released from potential amylase activity. Samples were taken at 0, 10, 60, 120, and 180 min and heated to 70°C for 5 min to stop any further enzymatic activity. Levels of glucose in the samples were then analyzed via an enzymatic assay. Triplicate samples were taken at each time point, and the experiment was repeated three times. The pH of the wort was also taken at each sampling period. Statistical analysis (*t* test) was conducted to determine significant differences in glucose levels between the mash containing glucose and the control. Glucose analysis showed a significant increase in glucose levels over time compared to the control. The control (no lactose added) started at 0.01 g/L of glucose and increased to 0.79 g/L over the 3 hr. The treatment (lactose added) started at 0.02 g/L of glucose and increased to 9.2 g/L of glucose over the 3 hr. The level of glucose after 3 hr was significantly different between the control and the treatment. These results indicate that barley contains an endemic beta-galactosidase in sufficient quantities that a mash profile incorporating a step at the enzyme's optimum temperature results in significant lactose hydrolysis. This opens the possibility of utilizing lactose and lactose-containing foods, such as acid whey, as fermentable adjuncts in brewing and lays the foundation for new potential beer styles. Further research will look into further mash optimization for enzyme activity, as well as whether enzyme activity varies among grain varieties.

Marie Lawton is a graduate student at Cornell University. She completed her bachelor's degree in 2016 at the University of Massachusetts Amherst. Currently she is studying food microbiology and investigating new techniques in food safety.

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HS-SPME-FID–driven beer profiling targeting aroma-active monocarboxylic acids

Schubert, C.[1]; Thoerner, S.[1]; and RETTBERG, N.[1], (1)VLB Berlin, Berlin, Germany

Beer contains numerous short- and medium-chain monocarboxylic acids. These are either released during fermentation, yeast autolysis, or they originate from raw materials. Raw material-derived monocarboxylic acids are primarily associated with hop bitter acid synthesis and degradation. Their particular role in dry-hopped beer has been discussed recently, surely they contribute to the complex flavor of these products. In brief, short- and medium-chain acids contribute to beer flavor and quality due to two primary reasons: first, fatty acids themselves are aroma active; second, they act as key precursors for flavor-active ethyl esters (e.g., ethyl hexanote or ethyl butyrate) in beer. Both aspects imply the (increasing) demand for suitable tools for their instrumental analysis. Short- and medium-chain acids are usually analyzed by GC, whereas different methods of sample preparation and detection have been published. Generally, the assays for food and beverage analysis differ strongly with respect to manual handling, use of toxic solvents, degree of automation, and method performance (analyte spectrum, working range, etc.). In order to meet the demands of practical brewers, the current paper describes the development and application of an HS-SPME-FID method for beer profiling toward aroma-active short- and medium-chain monocarboxylic acids. Analysis results for commercial beers and process intermediates are presented to establish an understanding of variables that fundamentally influence acid concentrations in beer.

Nils Rettberg (born 1983) is a trained brewer and maltster, holding a diploma in biotechnology with a focus on brewing science from TU Berlin (Germany). Initiated by his diploma thesis on "Flavor Active Epoxydecenals from Lipid Oxidation" he developed a deep interest in the analysis of molecules that make beer taste either terribly good or horribly stale. From 2011 to 2014 Nils performed his doctoral thesis on "Comprehensive Analysis of Hop Secondary Metabolites." Simultaneously, he was a research associate at TU Berlin (Chair of Bioanalytics) and VLB Berlin (Research Institute for Special Analyses), where he was involved in both research and teaching. In January 2015 Nils became head of the VLB Research Institute for Special Analysis. Since October 2015 Nils has been in charge of the VLB Research Institute for Instrumental Beer and Beverage Analysis.

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Dilute and shoot—Comprehensive LC-Q-ToF-MS analysis of beer bitter acids

Hildebrandt, J.[1]; Thoerner, S.[1]; and RETTBERG, N.[1], (1)VLB Berlin, Berlin, Germany

Bitterness is a primary quality attribute of many beer styles. Depending on the product type, a wide range of bitter acids is present in commercial beers. Whereas light lagers mainly contain iso-alpha-acid isomers and/or their light stable analogues, late- and dry-hopped beers are characterized by the presence of alpha-acids, beta-acids, as well as their oxidation products. To a certain extent, all of these compounds contribute to beer bitterness and affect head retention and flavor stability. All-in-all, the list of relevant compounds is steadily growing, leading to an increasing demand for suitable analytical tools. In research related to beer bitterness, liquid-chromatography coupled to mass-spectrometry (LC-MS/MS) has been extensively used. Assays to quantify individual sets of hop bitter acids, as well as to monitor certain transformation reactions have been published. For this, triple quadrupole mass spectrometers were used. In order to ensure sensitive and selective analysis these instruments were operated in multiple reaction monitoring (MRM) mode. The major drawback of triple quadrupole mass spectrometers is their limited capability for substance identification. This drawback can be eliminated by use of high-resolution (hybrid) mass spectrometers that enable superior performance in both, quantification and identification. The current paper summarizes the development and application of a LC-Q-TOF-MS–based method for quantitative analysis of alpha-acids, beta-acids, iso-alpha-acids, reduced iso-alpha-acids, humulinones, hulupones, xanthohumol and iso-xanthohumol. In addition to this targeted dilute and shoot assay, strategies for identification of bitter acid transformation products using high-resolution mass spectrometry are presented.

Nils Rettberg (born 1983) is a trained brewer and maltster, holding a diploma in biotechnology with a focus on brewing science from TU Berlin (Germany). Initiated by his diploma thesis on "Flavor Active Epoxydecenals from Lipid Oxidation" he developed a deep interest in the analysis of molecules that make beer taste either terribly good or horribly stale. From 2011 to 2014 Nils performed his doctoral thesis on "Comprehensive Analysis of Hop Secondary Metabolites." Simultaneously, he was a research associate at TU Berlin (Chair of Bioanalytics) and VLB Berlin (Research Institute for Special Analyses), where he was involved in both research and teaching. In January 2015 Nils became head of the VLB Research Institute for Special Analysis. Since October 2015 Nils has been in charge of the VLB Research Institute for Instrumental Beer and Beverage Analysis.

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Optical in-line alcohol measurement

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Accurate alcohol measurement is a critical part of the brewing process. Conventional in-line methods to determine the alcohol and extract concentration in beer are based on measuring and calculating two independent parameters like density, ultrasonic sound speed or refractive index. As a consequence extra handling steps are required such as product-specific calibration and compensation for carbon dioxide. The patented new optical in-line measuring principle overcomes these and makes the measurement easier than the current benchmark. To reduce these extra handling steps and enable a more accurate measurement of alcohol for beer an optical in-line sensor has been developed. The alcohol sensor consists mainly of a light source and a spectrometer. During the measurement light is transmitted through the beer pipe. The NIR-light beam is received in the spectrometer. By means of the spectrometer the light intensity in the wavelength band for alcohol is measured, and the water spectrum is subtracted. Within this wavelength band the surface area is determined by the electronics. This surface area is a direct measure for the alcohol concentration. By applying this direct alcohol measurement technology the continuous monitoring of the beer quality is simplified and becomes more reliable. This novel technology is applicable for filtered and low-turbidity beers up to 20% alcohol; higher turbidity beers are currently under investigation. Alcohol-free beer, beer-mix drinks and products with higher alcohol concentration can be measured with less operator intervention. Measurement can take place continuously in-line at critical locations in the production line—typically after filtration, carbonation and blending/mixing and in front of the filler. Using the optical In-line sensor technology an improved ethanol measurement is obtained: without the necessity of taking the extract content into account; without the necessity for product-specific calibration due to constituents other than ethanol in the product to be measured; and without the necessity of compensating for the carbon dioxide content.

Frank Verkoelen studied mechanical engineering at HTS Venlo and finished in 1982. Since 1984 Frank has worked for Pentair Haffmans, starting as a project engineer for CO2 recovery. In 1987 he changed to R&D project management and then became the R&D Manager. In 2001 Frank changed to product manager (PM) QC and became senior PM responsible for sales of QC equipment and in-line equipment. Since 2012 he has been the manager of strategic projects QC equipment and in-line equipment.

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Rapid testing methods for beer analysis using infrared spectrometry and quality trait analysis

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Infrared spectroscopy is becoming a widely used technology in a variety of industries, such as food/ingredients, agricultural commodities, beverage, nutraceuticals, and others. Infrared spectroscopy offers rapid, nondestructive, multicomponent analysis with little or no sample preparation, making it an attractive analytical technique. The recent advances in the accuracy and reliability of this method has added to its increasing popularity. Infrared spectroscopy for both hops analysis and finished product beer analysis is described in this presentation. Hops are analyzed for alpha-acids by near-infrared (NIR) spectroscopy and finished product beer is analyzed for a number of traits using mid-infrared (MIR) spectroscopy. For hops, a small portion of hops is placed in a cup and scanned, with no additional sample preparation.

For beer, bitterness (IBU), alcohol content (ABV), extracts, fermentation, specific gravity, calories, color, and pH are analyzed simultaneously using only a drop of beer. For both instruments, scanning and results are completed in approximately 2 min or less. The quality trait analysis (QTA) technique and instrumentation will be presented, along with the performance criteria (i.e., method errors and ranges) for each parameter that is tested for beer and hops.

Anthony Lai is the commercial manager at Eurofins QTA.

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Rapid quantification of major hop aroma compounds in beer by static headspace GC-MS

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Hop aroma is a primary quality characteristic of many beer styles. It is a rather complex phenomenon caused by multiple hop-derived metabolites and their derivates formed by (bio) chemical reactions during brewing. Numerous techniques for quantification of hop aroma compounds in beer have been published; the vast majority are GC-MS based. Since there is no short and universal list of relevant hop aroma compounds; analysts use custom-made target lists, typically including 20 (or more) analytes. In order to maximize the number of target compounds, selective extraction techniques such as SPME or SBSE and long GC run times are applied. In order to maintain consistent data, elaborate calibration protocols to minimize drifts caused by abrasion of extraction media (fibers, stir bars) are required. All-in-all, hop aroma analysis appears to be a rather complex and costly discipline. Indeed, there are many good reasons for comprehensive multi-analyte methods, but in many cases questions of practical brewers can be described by rather simple data sets. Respecting the need for fast, simple, and cost-effective assays, the current paper introduces a rapid static headspace GC-MS method for quantification of myrcene and linalool by a stable isotope-dilution assay. The optimized workflow enables the analysis of 5 samples/hour; method validation was performed by a comparative study using HS-SPME-GC-MS/MS as a reference method.

Nils Rettberg (born 1983) is a trained brewer and maltster, holding a diploma in biotechnology with a focus on brewing science from TU Berlin (Germany). Initiated by his diploma thesis on "Flavor Active Epoxydecenals from Lipid Oxidation" he developed a deep interest in the analysis of molecules that make beer taste either terribly good or horribly stale. From 2011 to 2014 Nils performed his doctoral thesis on "Comprehensive Analysis of Hop Secondary Metabolites." Simultaneously, he was a research associate at TU Berlin (Chair of Bioanalytics) and VLB Berlin (Research Institute for Special Analyses), where he was involved in both research and teaching. In January 2015 Nils became head of the VLB Research Institute for Special Analysis. Since October 2015 Nils has been in charge of the VLB Research Institute for Instrumental Beer and Beverage Analysis.

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Automation of wet chemistry methods in brewery quality labs

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Many common tests used in the brewing industry are of the basic wet chemistry variety. Two of the most common and most labor-intensive tests used in the laboratory are sulfur dioxide (SO_2) and alpha-amino nitrogen analysis—both vital tests for the monitoring of yeast health and wort nutrition. Advances in technology have allowed laboratories the benefit of accurately and simply automating these analysis, thereby increasing a laboratory's testing capabilities without the need for more personnel and supplies. This work will focus on cost analysis and recovery of investment of some of the more commonly used instruments available in the market for analysis of sulfur dioxide (SO_2) and alpha-amino nitrogen.

Maydelin H. Espinosa received an M.S. degree in environmental sciences and a B.S. degree in chemistry, both from the University of Havana, Havana, Cuba. She began employment with the National Center for Scientific Research (CNIC) in 1998 as a chemist in the polymer laboratory, synthesizing co-polymers for pharmaceutical use in time-release capsules. Since 2006, she has worked for Molson Coors Canada in the quality lab, and in 2007, she transitioned to the Molson Coors central laboratory in the role of chemist. She has published her polymer work in Polymer (42:3393-3397, 2001).

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The influence of barley variety and malt modification on the wort amino acid spectrum

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Free amino acid (FAN) has been regarded as an important index to predict yeast fermentation and beer quality. Amino acid utilization by yeast during brewer's wort fermentation is seen as linked to flavor profile, thus the amino acid spectrum of wort also had a large impact on yeast flavor and beer quality. Here, the influences of malting barley variety and malt modification on wort amino acid spectrum were investigated. Fifty commercial malts from Canada, Australia and China were mashed using the Congress mashing protocol, and the amino acid composition of wort was analyzed. Principal component analysis showed a significant difference between malts from different regions and the malt from Canada close to that from Australia. Although no obvious difference was found in total amino acids level, relative proportions of individual amino acids were remarkably different. Malts from China were rich in B group amino acids and that from Canada and Australia were abundant in C group amino acids and proline. Furthermore, the effect of malt modification (Kolbach index [KI] 33–53) on the amino acid spectrum was investigated. Results showed that the total amino acids level was enhanced with the increase of KI. However, the changes in relative proportions of individual amino acids were different. The proportion of histidine and proline decreased with increased KI. While the proportion of tyrosine, threonine, leucine, phenylalanine and isoleucine were enhanced with increased KI. In conclusion, this research on the factors influencing wort amino acids spectrum allows brewers to keep better control of wort FAN according to malt blending and malting process, leading to a steady wort composition.

Shumin Hu, born in 1984, received a Ph.D. degree in ferment engineering from Shandong University in Jinan, China. She joined in State Key Laboratory of Biological Fermentation Engineering of Beer, Co. Ltd. in 2011 as a post-doctoral researcher. After she finished her postdoctoral work in 2014, she continued to work in Tsingtao Brewery Co. Ltd. and focuses on the research of starch degradation, including amylase, malt quality evaluation, process control, etc.

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Measuring beer color—A different language

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Sensory evaluation is very important in the evaluation of beer. Specifically, color and visual appearance are critical factors in consumer acceptance, while also being an indication of overall quality and process variation. The ASBC method for beer color and turbidity is: ASBC Beer-10, Color of Beer Part A, Spectrophotometric Color Method. The ASBC color metric is based on a spectral absorbance measurement at 430 nm of clarified beer using a UV-VIS spectrophotometer. The ASBC Beer Color scale has a range of approximately 1 to 11 units. The higher the ASBC Beer Color value, the lighter the beer. ASBC turbidity is also based on a spectral method that measures absorbance at two points—one in the blue (430 nm) and one in the red (700 nm) region. If the absorbance is significantly different at these two points, then ASBC turbidity is rated as being "turbid," if not then the rating is "free of turbidity." The key industry challenges of appearance measurement for beer are that: the current color measurement method does not reproduce how the eye sees color; a beer color number can be the same for products that are visually different (data and examples discussed); turbidity is generally not quantified, only qualitatively evaluated (data and examples discussed); and visual consistency from lot-to-lot of the same beer type would also be important. An additional global analytical method can be utilized for precise color and turbidity evaluation. This additional analytical method uses well-established colorimetry and color science. Both ASBC color and turbidity metrics use objective quantification as a basis. Both are more consistent than visual evaluation of color and scattering in beer samples. However, for ASBC color, only a single wavelength is used for quantification. The CIE colorimetric scales, defined in the paper, offer a complete quantification of product color. The situation regarding ASBC turbidity is similar. While based on spectral measurement and useful for reporting for product specification, the reported values are based on only two wavelengths. For this situation, either ASTM D1003 transmission haze or NTU turbidity measurement can be utilized. Both report product scattering in a quantifiable scale based on spectrophotometric measurement. The specifications and methods will be discussed. In addition, the talk will describe how color science is used to evaluate and communicate color and provide a more accurate color measurement, including color scales and basic color measurement techniques. Turbidity evaluation and quantification for beer will also be discussed.

Paul Barnes has over 30 years of experience in analytical instrumentation methods. He has spoken to numerous food and beverage industry groups on color science and applications. He holds a B.S. in chemistry from the University of Maryland, College Park, and M.S. degree from Johns Hopkins University.

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Predicting market preference from reviews of professional tasting panels on the Gastrograph system

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The Gastrograph system is a sensory platform that enables panelists to describe the product they are tasting across 24 flavor attributes and somatosensations supplemented by the specific reference flavors the panelists taste in any specific product. At the end of each review, the panelists are asked to assign a perceived quality score for that product. Most sensory panels at breweries do not contain a stratified sampling of the general population, so standard statistical methods cannot be employed in order to understand the preferences of the average beer consumer. To project the preferences of professional panelists onto the preferences of the general population, reviews that were completed on the Gastrograph system were sampled from, in accordance with the tasting experience level distribution of the general population. The techniques LFDA (local Fisher discriminant analysis) and PAM (partitioning around medoids) were used to maximize between-product similarity and minimize within-product similarity in flavor profile. The random forest method is then utilized to predict the distribution of perceived quality scores the general population would assign given any set of reviews, with built-in considerations for the class of beer and the tasting experience of the panelists.

Before starting Analytical Flavor Systems, Jason Cohen was the founder and executive director of The Tea Institute at Penn State, which oversees 20+ researchers in 5 fields of study in traditional Chinese, Japanese, and Korean teas. Jason did his research in sensory science and data mining, eventually developing the Gastrograph system after three and a half years of research. Jason is a professional coffee, tea, and beer taster.

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Selection and use of response scales in brewery taste tests

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Most taste tests conducted in breweries make use of some form of response scale. These range from simple binary text scales (e.g., go, stop) or simple numeric scales (e.g., 1, 2, 3, 4, 5) to more complex scales that facilitate greater discrimination between samples (e.g., 15-point labeled category line scale). The type of scale selected for any particular type of taste test can have a profound effect on the performance of the test and the results generated from it. This is due to the properties of the scale itself, as well as the effect of the scale on the psychology and behavior of the taster. The purpose of this paper is to describe the different types of response scales available to breweries for use in taste tests, indicate how and when they are best deployed, and provide examples of good practice in their use. In addition, optimal approaches to training of assessors in the use of different types of response scale will be discussed.

Bill Simpson is director of Cara Technology Limited, a specialist in beer taste panel development and yeast supply to the global brewing industry. After almost a decade with Tennent's in Glasgow, Scotland, Bill joined the Brewing Research Foundation near London, where he spent almost 10 years carrying out research into beer technology. Since establishing Cara Technology in 1995 he has consulted for more than 500 breweries in over 70 countries and has grown the company into a major provider of technical services to breweries throughout the world. He has published more than 120 technical papers, patents and book chapters in the area of brewing technology and is the inventor of stabilized beer flavor standards used to train thousands of professional beer tasters all over the world.

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The future of brewing in a biobased economy

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The global population is growing, set to reach over 9 billion people by 2050, and this will create significant challenges. For instance, the Food and Agriculture Organisation of the United Nations (FAO) have projected that this growth will require 70% more food be produced than in 2005–2007. In the future, the food market, to which brewing contributes significantly, will be required to be sustainable to survive. This does not mean only to be economically sustainable, but environmentally as well. The broader concept of sustainability is that we have an opportunity to reduce our demands on the planet's resources. As an industry, we work with both renewable and finite resources, but even the renewable resources increasingly have other demands on them. Many sizes of brewing companies have sustainability policies and frameworks that they are working within; the best will be using sustainability to drive their businesses forward. The brewing industry has already on many levels recognized the impact we have on the world around us, and that the environment has on our resources. Great strides have been made in understanding how brewers can reduce their water and carbon footprints, research has been undertaken into developing drought-resistant barley crops, and there is greater interest in the utilization of novel grains for brewing. Many brewers feed their by-products back into the local agricultural economy. However, we have the potential to go beyond this through the valorization of these streams. Valorization adds value to our outputs and, therefore, could potentially represent an additional income stream. This review will look outside the traditional routes for brewery co-products beyond animal feed and fertilizer and ask can we as brewers work our way to globally become an essential part of the bioeconomy? Can the bioeconomy create new opportunities and markets for all sizes of brewing companies? And, are there any lessons we can learn from other beverage industries that can be applied to brewing?

Dawn Maskell is the director of the International Centre for Brewing and Distilling at Heriot-Watt University in Scotland (U.K.). Dawn has a Ph.D. degree from Oxford Brookes University, where she researched brewing yeast aging and stress tolerance under the tutelage of Prof. Katherine Smart. Prior to this Dawn gained an honors degree in brewing and distilling from Heriot-Watt University. Before joining the ICBD in 2015 she worked on the valorization of brewery and distillery co-products and is a co-founder of a spin-out company, Horizon Proteins, which utilizes protein from the co-products generated by the Scotch malt whisky industry. Dawn is a member of the American Society of Brewing Chemists and the Institute of Brewing and Distilling, with a Diploma in Brewing, and is an accredited chartered scientist. Dawn is also on the Board of Examiners for the Institute of Brewing and Distilling and the programme committee for the Worldwide Distilled Spirits Conference 2017.

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Quantification of hop acids present in spent brewer's grain

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Brewer's spent grain has commercial and nutritional value, yet it may contain hop acids. This study focused on the adaptation of ASBC Method of Analysis Hops-14 to quantify residual hop acids contained in brewer's spent grain. Trials to determine the presence of iso-alpha, alpha, and beta hop acids in dried spent grain were carried out to test the feasibility of detection and quantification by HPLC analysis. Dose and recovery studies were carried out to evaluate the recovery rates in spent grain dosed with a mixture of purified hop acids. Once the method was validated for its ability to detect the hop acids under controlled conditions, an evaluation of limit of detection (LD) and limit of quantification (LQ) was carried out to better understand the limitations of the modified Hops-14 method. Recovery rates of the various hop acids ranged from 94% to 106%. The method yielded LD and LQ values of 0.4–1.0 mg/L and 0.6–1.4 mg/L in extraction solution, respectively, depending on the hop acid component in question. Detection limits in the spent grain were influenced by the spent grain/extraction solvent ratio and were 1.4, 1.0 and 1.8 mg/L for total iso-alpha-, alpha- and beta-acids, respectively. Further processing of the extraction solvent was deemed not necessary and clouded the chromatogram with excess baseline signal from the grain matrix. With this adaptation of Hops-14, it is feasible to evaluate a sample of spent brewer's grain for the presence of iso-alpha, alpha, and beta hop acids.

Bradley Barnette is a first-year master's degree student in the Brewing Science Department at Oregon State University. He received a bachelor's degree in food science and technology, as well as a bachelor's degree in general science from Oregon State University. His project work thus far has included method development and chemical analysis of hop samples for the Oregon State hop breeding program. His current research interests are focused on beer bitterness, beer staling and flavor stability, hop analytics, and instrumental analysis of hops and hop products.

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Evaluation of the Beer SpoilerAlert™ assay: Sensitivity, specificity, and adaptability

Bocioaga, D.[1]; Kozak, S.[1]; Mix, K.[1]; Morse, S.[1]; Sorensen, K.[1]; McGuire, C.[1]; TRABOLD, P.[1]; MacLeod, A.[2]; and Spizz, G.[1], (1) Rheonix, Inc., Ithaca, NY, U.S.A., (2)Hartwick College Center for Craft Food and Beverage, Oneonta, NY, U.S.A.

Despite the hostile environment beer presents to the growth of most bacteria, strains of lactic acid bacteria (LAB) have evolved mechanisms allowing survival and growth in beer that ultimately may lead to spoiled product. Identification of spoilage organisms in beer has typically been done using culture-based detection methods, taking as much as a week to obtain results. Furthermore, the current methods test only for the presence of the bacteria, but do not identify whether the detected strain would actually propagate in the beer in which it was found. This is relevant in the rapidly growing brewing industry distinguished by the development of beers that differ significantly in levels of international bitterness units (IBUs) determined by the concentration and types of hops used in the recipe. In contrast, nucleic acid-based detection methods enable more rapid determination of the presence of potential spoiler organisms. Similarly, if the appropriate sequences are analyzed, these methods also distinguish not only the presence of the organism, but whether it has the capability of growing in the presence of iso-alpha-acids derived from hops. The purpose of this study was to evaluate sensitivity, specificity, and adaptability of the Rheonix Beer SpoilerAlert™ assay, a fully automated sample-to-results multiplexing molecular detection kit. The assay targets four distinct sequences enabling rapid detection of potential spoilage LAB and four sequences informing the presence of hop-resistant genes. Furthermore, spoilage concerns for brewers are not limited to bacteria, but also extend to the presence of yeast. Therefore, the assay also targets three yeast sequences demonstrating the presence of *Saccharomyces cerevisiae* (brewer's yeast), *S. cerevisiae* var. *diastaticus* and *Brettanomyces bruxellensis.* The presence of *S. cerevisiae* var. *diastaticus* is of particular concern due to its significantly close similarity to brewer's yeast and, thus, could remain easily undetectable until it spoils beer in the marketplace. *B. bruxellensis* provides another problem in that it is some-

times used to make specific beers, and thus, the risk increases of cross-contamination in the same brewery between a *B. bruxellensis* containing and non-containing beer. Results of the study demonstrated sensitivity for all target organisms of approximately 10^4 cfu/mL and less than 10 cfu/sample before enrichment. Data will also be shown regarding the adaptability of the system for use with all types of matrices expected from the brewery, including, but not limited to, in-process samples, final product, individual colonies, and environmental samples. The specificity of the assay for the targets via exclusivity analysis will be presented. This rapid method for the multiplexed detection of 11 gene sequences from a single sample reduces processing time compared to culture and provides a genetic characterization of the bacterial genes that confer hop resistance. This provides brewers with better information regarding the presence of spoilage microorganisms in their products and brewery environment and allows them to make more rapid and informed decisions regarding safe delivery of product.

Peter Trabold received a B.A. degree in biology and philosophy, an MBA, and a Ph.D. degree in molecular and cellular biology from the University at Buffalo. He began working for ZeptoMetrix Corporation developing non-infectious molecular controls for the infectious disease marketplace. Currently, Peter is the director of business development at Rheonix, Inc., helping to develop fully automated, multiplexed, molecular assays for food, beverage, and clinical markets. In addition, Peter is a former president of the Western New York branch of the American Society for Microbiology.

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Role of glutathione in yeast growth and fermentation for beer and wine production

PAUMI, C. M.[1]; Chowning, S.[1]; Schwarze, T.[1]; and Fugate, D.[1], (1)Department of Chemistry, Eastern Kentucky University, Richmond, KY, U.S.A.

Over the last 5–10 years a number of groups interested in decreasing free radicals during the fermentation and bottling processes of beers and wines have examined mechanisms to increase GSH content and excretion by yeast during the fermentation process. These studies have utilized classical and modern genetics to increase GSH content via increasing the GSH synthesis proteins Gsh1p and Gsh2p. The initial studies indicate that increasing yeast GSH cellular content and GSH excretion does increase the antioxidant capacity of the must and wort while also increasing the stability of beer and wine flavor post-bottling. Further, a recent study published in 2014 examining Gp×1p and catalase (Cttp1p) mediated protection against oxidative stress support the role of glutathione as an important protective antioxidant in yeast during fermentation. Elevated levels and activity of Gp×1p and Ctt1p contribute to elevated cellular and extracellular GSH. Together these studies suggest an important role for the antioxidant glutathione-based system in protecting yeast from oxidative stress . However, it is important to note that GSH is in equilibrium with GSSG and that this delicate balance is maintained via a complex multi-protein system containing the GSH synthesis proteins, Gsh1p and Gsh2p, glutathione reductase (Glr1p), and glutathione utilizing and linked proteins such as glutathione peroxidase (Gp×1p, Gp×2p, and Gp×3p), Ctt1p, and superoxide dismutase (Sod1p and Sod2p). To date no lab has examined how these systems work together to regulate oxidative stress during fermentation and regulate oxidation in bottled beer and wine. Our lab has utilized classical genetic approaches, molecular biology, and the yeast deletion collection to increase GSH content of a standard laboratory strain of *Saccharomyces cerevisiae* (BY4741 background). We have measured and compared fermentation efficiency in each of the deletion and control and a number of beer brewing strains. For all strains biomass, relative oxidative stress, and cellular GSH levels were measured. Oxidative stress was measured as a function of DCFDA fluorescence, a measure of general reactive oxygen species. The DCFDA results were then compared to measured levels of GSH. Ultimately, we hope that by exposing yeast-brewing strains to an oxidant inducer, our lab will selectively induce genes involved in GSH synthesis and recycling for use in the brewing industry.

Christian Paumi is a professor of fermentation microbiology at Eastern Kentucky University in the Department of Chemistry and is a faculty member in the fermentation science program. As a recent addition to the Department of Chemistry, Christian has been involved in the establishment of the new fermentation science program, including teaching "Fermentation Microbiology" in spring 2017. Christian did his post-doctoral fellowship at Johns Hopkins University in the Department of Cell Biology (Baltimore, MD) and obtained his Ph.D. degree in biochemistry and molecular biology from Wake Forest University in the Department of Biochemistry and Molecular Biology. Christian is a member of the newly formed East Coast-Midwest Alcohol Beverage Initiative Group; actively collaborates with a brewing and distilling analytical service, Ferm Solutions of Kentucky; and interns at Rock House Brewing in Lexington, KY.

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New tools and method for concentration of microorganisms from American lager beers for spoilage detection

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Beer spoilage organisms and contamination present a major risk for the brewing industry. As such, microbiological testing for these organisms is necessary throughout the brewing process. However, most laboratories still use conventional cultivation methods, which are time-consuming—requiring 3 to 5 days for beer to be released to the market. Rapid microbiological analytical methods offer great potential for increasing the reliability of spoilage detection in beer while reducing labor costs and product hold times; however, small analysis volumes limit the usefulness of these methods. Furthermore, development of rapid detection methods has far outpaced development of sample collection and concentration techniques, which are necessary to enable detection of low microbial concentrations in the brewing process. The Concentrating Pipette is an automated, rapid bio-concentration device. Samplers are first filtered through high-flow, single-use pipette tips capturing microorganisms from the fluid sample matrix. Once the microorganisms are captured, the automated wet-foam elution process recovers and delivers the microorganisms into a microliter volume of clean buffer ready for analysis by modern or classical methods. In this study, InnovaPrep's Concentrating Pipette was investigated as a bridge to concentrate 12 oz of beer into volumes more appropriate for rapid detection methods. The high level of carbonation in beer created a significant hurdle in applying the Concentrating Pipette to this application. During processing significant quantities of CO_2 are released from the beer, causing the hydrophilic membrane filter to lock up. Although there are numerous decarbonation methods, none of these methods were able to reduce the amount of residual CO_2 that allowed an entire can of beer to be processed by the Concentrating Pipette. A method was devised to create nucleation sites in glassware to allow for more efficient decarbonation. In short, 12 oz (355 mL) of room temperature American lager beer was poured into glass containers that were sandblasted to create a large surface area of nucleation points to help in the degassing process. The beer was incubated at 4°C for 10 min to increase the solubility of CO_2. The samples were then concentrated using a 0.4 µm polycarbonate track etched,

disposable Concentrating Pipette tip. On average, sample process time took 10.1 min ($n = 6 \pm 1.1$), with an average elution volume of 317 µL ± 19.3, with nominal concentration factors of 500×. Moreover, when beer cans were kept at 37°C prior to pouring and incubation at 4°C, the average sample process time averaged 6.5 min. Overall, this demonstrates that American lager can be concentrated to smaller volumes that are more appropriate for rapid detection methods in a relatively short amount of time.

Michael Hornback is director of laboratory operations at InnovaPrep LLC. Michael graduated with his Ph.D. degree in microbiology from East Carolina University in 2006 and has held post-doctoral fellowship positions at Emory University and Kansas University Medical Center. He has over 10 years of experience in the area of bacterial research, with a heavy emphasis on molecular biological techniques. Michael is a senior scientist at InnovaPrep and has developed methods for sample processing for the Concentrating Pipette and has established viral, DNA, and protein protocols used in ongoing research and development projects. He is currently director of laboratory operations and supervises InnovaPrep R&D and demonstration testing.

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Spoilage risk-based analysis of *Lactobacillus* and *Pediococcus* brewery isolates in beers having diverse properties

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A major challenge in maintaining beer quality is early detection of spoilage microorganisms before they have the ability to produce unintended flavors and aromas. Spoilage organisms can be diverse and present different quality risks based on their potential to thrive in beer and in the brewery. Early detection coupled with risk-based analyses can provide invaluable information to quality-centric brewers. A novel molecular diagnostic assay, Veriflow® brewPAL, was developed to provide accurate and sensitive detection of beer-spoiling *Pediococcus* and *Lactobacillus* species in under 3 hr. In this study, Veriflow® brewPAL technology was used to assess bacterial growth in beers having diverse properties. Numerous factors may influence the ability of *Lactobacillus* and *Pediococcus* species to metabolize and affect the quality of beer, including levels of hop resistance genes in bacterial isolates and percent ABV, IBU, gravity, malt builds and respective substrates in beer formulations. The effects of these factors on *Lactobacillus* and *Pediococcus* growth were evaluated with the ultimate goal of developing a comprehensive, validated model for beer spoilage risk assessment that could be used by breweries to preserve the quality and, therefore, the taste and value of the beer they produce. *Lactobacillus* and *Pediococcus* strains were isolated from different locations within a brewery setting. Each isolate was genetically characterized to determine strain identity and the hop resistance gene profile. Following characterization, select strains were grown in beers having distinct properties in order to determine the factors that are major predictors of spoilage risk. Bacterial growth in each beer was measured and quantified using the Veriflow® brewPAL system to determine overall risk of spoilage, which was subsequently correlated to the properties specific to each beer. While ABV and IBU are important factors that can influence the risk of beer spoilage, the results of these studies revealed additional properties are strong modulators of bacterial growth, including the utilization of specialty malts. These findings can be used as a guide to help predict whether conditions within a particular beer are favorable for rapid bacterial growth and subsequent spoilage, thereby providing brewers with the ability to make early and informed decisions to maintain the quality of their products.

Kelly Maher was born and raised on Long Island, NY. She graduated from Northeastern University with a B.S. degree in biology in 2012. She has been working in quality and product development for five years. Her love of craft beer came from her time working at Sam Adams, and her love of quality assurance came from her work at Estee Lauder Companies.

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Yeast health and the impact yeast vitality has on beer flavor development during fermentation

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The subject of yeast vitality has conventionally been very difficult to quantify against yeast performance. The main limitation of these assessments is the fact that each vitality test only evaluates a certain aspect of yeast physiology, thus making vitality difficult to correlate to yeast performance. Fermentation studies were conducted to relate yeast health to fermentation performance and the corresponding yeast vitality assessment. Ale and lager yeast strains were subjected to commonly seen brewing stresses in order to quantify vitality measurements with yeast performance. The performance indicators evaluated were production of esters, higher alcohols and aldehydes, ability of yeast cells to reduce VDK and the ability of yeast cells to perform over consecutive generations. The results provided are baseline knowledge used for monitoring yeast health in order to produce more consistent beer products.

Laura Marques received a B.S. degree in chemistry from the University of Western Ontario and diploma in science laboratory technology from Fanshawe College in London, ON, Canada. She began employment at Diagnostix Inc. in 2001 as an R&D chemist working on effective mycotoxin regimens used in the national grain inspection industry. Since 2006, she has worked for Molson Coors Canada in the role of chemist at the central laboratory. In addition to serving on two ASBC subcommittees, Laura has published in the Journal of Soil Sciences for research on using yeast estrogen screen assays.

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High-gravity brewing for the craft brewer

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Ales and other beer styles that at one time may have been considered niche in many markets are enjoying huge growth in their popularity around the world. This is in no short measure due to the explosion of the craft brewing scene, where small brewers have had the flexibility to respond quickly to increasingly sophisticated consumer demands. Or, alternatively used these products to carve a niche in what is an increasingly competitive market. High-gravity brewing is a relatively simple technique that is well established in the production of many lager beers that is increasingly of interest to the craft brewer producing other styles of beers. The work presented here examined the impact of low (10°P), medium (15°P), and high (20°P) gravity worts on several strains of ale (*Saccharomyces cerevisiae*) yeast using lager yeast (*S. pastorianus*) as a control. Yeast viability and fermentation performance was monitored, and HS-GC-FID was used to detect changes in yeast metabolic by-product production. This work was undertaken to begin to fill the gap that surrounds the use of ale yeast in high-gravity fermentations, the clear majority of the published material being focused on lager yeast. Greater understanding of how ale yeasts perform under high-gravity conditions will allow users of these strains to consider the impact high-gravity brewing may have on their final product, while at the same time allowing an increase in production volume. The results of these preliminary studies found that, as was expected,

the higher the starting gravity the greater the fermentation time. The utilization of available free amino nitrogen also increased with gravity (between 5 and 15%). Examination of flavor compounds in diluted beer found that the production of esters and higher alcohols was strain specific. Most strains demonstrated an increase in the production of ethyl acetate, isobutyl acetate, whereas the concentration of total higher alcohols generally decreased with the increase in gravity. These results mean that the response of the strains investigated to worts with higher gravities are strain specific, and if utilizing high-gravity brewing techniques, as with lager yeast, trials will be needed to ensure that the final diluted sales gravity beer matches the profile of the original product. A great deal of further work is needed in this area; some small examples being needed to determine the impact on yeast physiology for these strains, the consequences of serial repitching and to investigate the influence of colored and specialty malts and grains in the production of these beers.

Dawn Maskell is the director of the International Centre for Brewing and Distilling at Heriot-Watt University in Scotland (U.K.). Dawn has a Ph.D. degree from Oxford Brookes University, where she researched brewing yeast aging and stress tolerance under the tutelage of Prof. Katherine Smart. Prior to this Dawn gained an honors degree in brewing and distilling from Heriot-Watt University. Before joining the ICBD in 2015 she worked on the valorization of brewery and distillery co-products and is a co-founder of a spin-out company, Horizon Proteins, which utilizes protein from the co-products generated by the Scotch malt whisky industry. Dawn is a member of the American Society of Brewing Chemists and the Institute of Brewing and Distilling, with a Diploma in Brewing, and is an accredited chartered scientist. Dawn is also on the Board of Examiners for the Institute of Brewing and Distilling and the programme committee for the Worldwide Distilled Spirits Conference 2017.

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Phylogenetic diversity of the bacterial and fungal communities of craft beers throughout the brewing process

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The craft brewing industry is increasing in popularity in the United States and includes regional breweries, microbreweries, and home brewing. A majority of craft beers contain innovative ingredients, such as fruits, herbs, and spices that provide novel organoleptic properties to the beer. The craft brewing process typically does not use a pasteurization or filtration step; therefore, the boiling process is the primary method of inhibiting bacterial growth. Any microorganisms introduced after boiling, or those that are not killed during boiling, are likely to participate in fermentation and end up in the final product. Previous culture-based studies have isolated bacteria and yeast from craft beers at specific time points, but little research has been done on the process as a whole, starting from raw materials and finishing with the final product. The objectives of this research are to (1) track microorganism development throughout the brewing process and (2) compare these results to environmental sampling of the brewhouse to infer the origin of the microorganisms and identify those that are persistent in the environment. Two craft breweries in northwest Arkansas were utilized as the sampling source. Five beer styles were sampled, each for two distinct batches. Swab samples were taken of the mash tun, the boil kettle, and the fermentation tank. Samples of the raw material include the malted grain, hops, and any other additional ingredient added during the process. During the brewing process, a sample during the mash, before boil, post-boil, after cooling, and during fermentation, were taken. The final samples were collected after fermentation, before filtering, after filtering, and final package (cans, kegs, or bottles). High-throughput sequencing using the Illumina MiSeq will be used to identify DNA found in the samples, using both bacteria and fungi universal primers. Initial results show that the average DNA concentration of environmental swabs is 8.26 ng/µL, 15.65 ng/µL at the pre-boil stage, and 13.28 ng/µL in post-boil samples. The highest average concentration of DNA was found at the fermentation stage around day 3 at 32.92 ng/µL. In a preliminary study on an "experimental" peach sour beer, a striking bacterial diversity (at least 17 different species in significant abundance) was observed. In another preliminary study, an ESB and a red ale canned for local distribution were found to harbor slightly different potential spoilers: *Lactobacilli* (98%) only for the red ale, *Pediococcus* (47%) and diverse *Lactobacilli* for the ESB. The expected results of the current study will allow brewers to have more knowledge about the possibility of microorganisms found in beer and could lead to further research on the role that microorganisms play in the quality of beer and the organoleptic properties of craft beer.

Lindsey Rodhouse is a graduate student at the University of Arkansas in Fayetteville, AR, earning her master's degree in food science, and expects to graduate in July 2017. She obtained her B.S. degree at the University of Arkansas in May 2015. Lindsey grew up in Kansas City, MO. Her passion for beer began in 2012 when she and her dad started home brewing. Since then, they have been brewing about twice annually. When Lindsey found out her master's thesis was on the topic of beer, she could not have been more thrilled. Throughout her undergraduate and graduate career, Lindsey has been involved in the Food Science Club, Alpha Delta Pi, and the National Society for Leadership and Success. During the summer of 2014, Lindsey worked at DuPont Nutrition and Health as a food protection intern. In June 2015, she studied abroad in Italy, where she learned about food commodities in Italy. After graduating with her master's degree, Lindsey will seek a career in the food industry.

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Atlas of yeast diversity in North and South America, the quest for hidden yeast

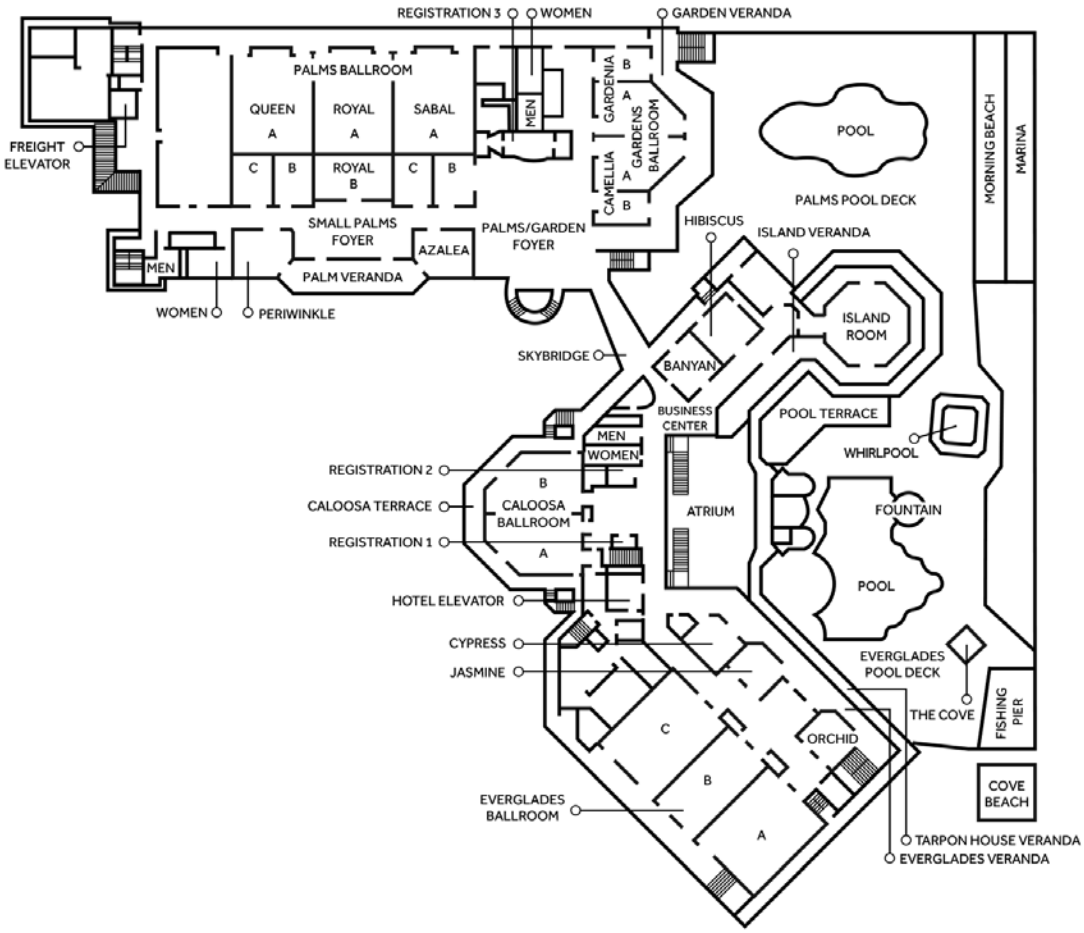
WINANS, M., West Virginia University, Granville, WV, U.S.A., Appalachian Brewer Research, Morgantown, WV, U.S.A.; and Gallagher, J. E., West Virginia University, Morgantown, WV, U.S.A.

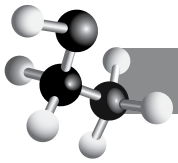
Improvement of yeast for brewing is a continuous process that creates specialized yeast. Many different industries have played a part in the specialization of yeast, as can be observed from the different strains used in brewing, winemaking, sake, cider, distillation, and biofuel production. Novel yeasts are left undiscovered in the natural environment around us. Eighty-four environmental samples yielded ninety-seven novel strains of yeast, including *Saccharomyces eubayanus* the parent species of the lager yeast. Samples were collected from the Appalachian Mountain areas of the Northeastern United States, including a 100-mile stretch of the Appalachian Trail; Southern Chile; and Southwestern Mexico. Incubation and isolation of cultures were performed in a temperature gradient on selective media. An initial screening was performed using different orthologous and essential housekeeping genes belonging to the *Saccharomyces* clade to detect each species through colony polymerase chain reaction (PCR). Following the initial screening, PCR amplification of the internal transcribes spacers (ITS) domain were sequenced by Sanger sequencing and compared for identification. The aim of this study is to collect, isolate, and characterize natural yeast isolates for use in commercial and private fermentations in order to harness aroma and flavor diversity. Future steps involve the processing of

these samples for use in the brewing industry. Hybridization with the *S. eubayanus* species isolated in this study is predicted to give rise to novel lager strains. It has been shown that hybrids have enhanced phenotypes, often surpassing parent strains. For example, hybrid vigor could improve their ability to handle stress from alcohol (late-stage fermentation) or produce higher/lower levels of esters or other chemical compounds. There are many chemical compounds of importance in industrial fermentations that are produced by yeasts, including the chemical families of aldehydes, ketones, alcohol, acids, and esters. The yeast strains captured here show diversity and have the possibility of being future targets for selective breeding and hybridization in a laboratory environment, with the ultimate goal of enhancing their phenotypes for commercial application.

Matthew J. Winans is a Ph.D. student of molecular genetics and toxicology at West Virginia University. He works beside his advisor, Dr. Jennifer Gallagher, as they use Saccharomyces cerevisiae for their model organism. Appalachian Brewer Research is his startup company, which specializes in yeast innovation for brewers. Matt received his B.S. degree in biology from Fairmont State. He is a member of the American Society of Brewing Chemists (ASBC) and locally is a leader of the Morgantown Area Society of Homebrewers (MASH). His broad range of specialized experiences gives a unique view to how he tackles obstacles. They range from recent patenting work to conducting underwater marine life transects for local fishermen of Turks and Caicos, to training animals at SeaWorld and Disney's EPCOT center, to running the sales and operations divisions at a medium-sized cleaning service corporation in the northeast. Looking forward in his career, Matt is searching for employment or a post-doc position focused in brewing science.

Facilities Map





Posters

Poster Hours

Posters will be open during the following times (subject to change):

Sunday, June 4	**11:00 a.m.–3:00 p.m.**	Poster Set-Up
	4:00–6:00 p.m.	Exhibits and Posters Opening Happy Hour
		4:30–5:30 p.m. All poster authors at poster
Monday, June 5	**12:30–2:30 p.m.**	Exhibits, Posters, and Lunch
		1:00–1:30 p.m. Odd-numbered poster authors at poster
		1:30–2:00 p.m. Even-numbered poster authors at poster
	3:30–5:00 p.m.	Poster Viewing
Tuesday, June 6	**9:45–11:30 a.m.**	Poster Viewing
	11:30 a.m.–1:30 p.m.	Exhibits, Posters, and Lunch
		12:00–12:30 p.m. Even-numbered poster authors at poster
		12:30–1:00 p.m. Odd-numbered poster authors at poster
	1:30–2:00 p.m.	Poster Take-Down

Poster Topics

33. Hahn, C., First wort hopping: An evaluation of its chemistry and sensory impact
35. Kirkpatrick, K., Investigating enzymatic power of hops
36. Huismann, M., Kinetic modeling of terpenes in packaged beers
37. Foster, R., Identification of hop varieties and growing region by gas chromatography-sulfur chemiluminescence
38. Zunkel, M., The language of hops—Practical applications of a tasting scheme for hop flavor
39. Putnam, K., Quantitative lateral flow assays for rapid determination of deoxynivalenol in barley and malt
40. Otama, L., Rapid automated method to measure alpha-amylase activity in malt
41. Takahashi, M., Development of a new highly sensitive method for predicting gushing potentials in beer products
42. Budner, D., Statistically significant difference between the aroma profiles of beer brewed from sorghum and barley malt
43. Budner, D., Analysis of fermentable carbohydrates using high-performance liquid chromatography in gluten and gluten-free beer
44. Cloninger, L., Alcohol by rapid distillation
45. Lawton, M., Mashing lactose into a fermentable adjunct
46. Rettberg, N., HS-SPME-FID–driven beer profiling targeting aroma-active monocarboxylic acids
47. Rettberg, N., Dilute and shoot—Comprehensive LC-Q-ToF-MS analysis of beer bitter acids
48. Verkoelen, F., Optical in-line alcohol measurement
49. Lai, A., Rapid testing methods for beer analysis using infrared spectrometry and quality trait analysis
50. Rettberg, N., Rapid quantification of major hop aroma compounds in beer by static headspace GC-MS
51. Hernandez Espinosa, M., Automation of wet chemistry methods in brewery quality labs
54. Hu, S., The influence of barley variety and malt modification on the wort amino acid spectrum
55. Barnes, P., Measuring beer color—A different language
56. Cohen, J., Predicting market preference from reviews of professional tasting panels on the Gastrograph system
57. Simpson, B., Selection and use of response scales in brewery taste tests
58. Maskell, D., The future of brewing in a biobased economy
59. Barnette, B., Quantification of hop acids present in spent brewer's grain
62. Trabold, P., Evaluation of the Beer SpoilerAlert™ assay: Sensitivity, specificity, and adaptability
64. Paumi, C., Role of glutathione in yeast growth and fermentation for beer and wine production
66. Hornback, M., New tools and method for concentration of microorganisms from American lager beers for spoilage detection
67. Maher, K., Spoilage risk-based analysis of *Lactobacillus* and *Pediococcus* brewery isolates in beers having diverse properties
68. Marques, L., Yeast health and the impact yeast vitality has on beer flavor development during fermentation
69. Maskell, D., High-gravity brewing for the craft brewer
70. Rodhouse, L., Phylogenetic diversity of the bacterial and fungal communities of craft beers throughout the brewing process
71. Winans, M., Atlas of yeast diversity in North and South America, the quest for hidden yeast

Exhibition

Thank you to all 2017 exhibitors for being part of the meeting!

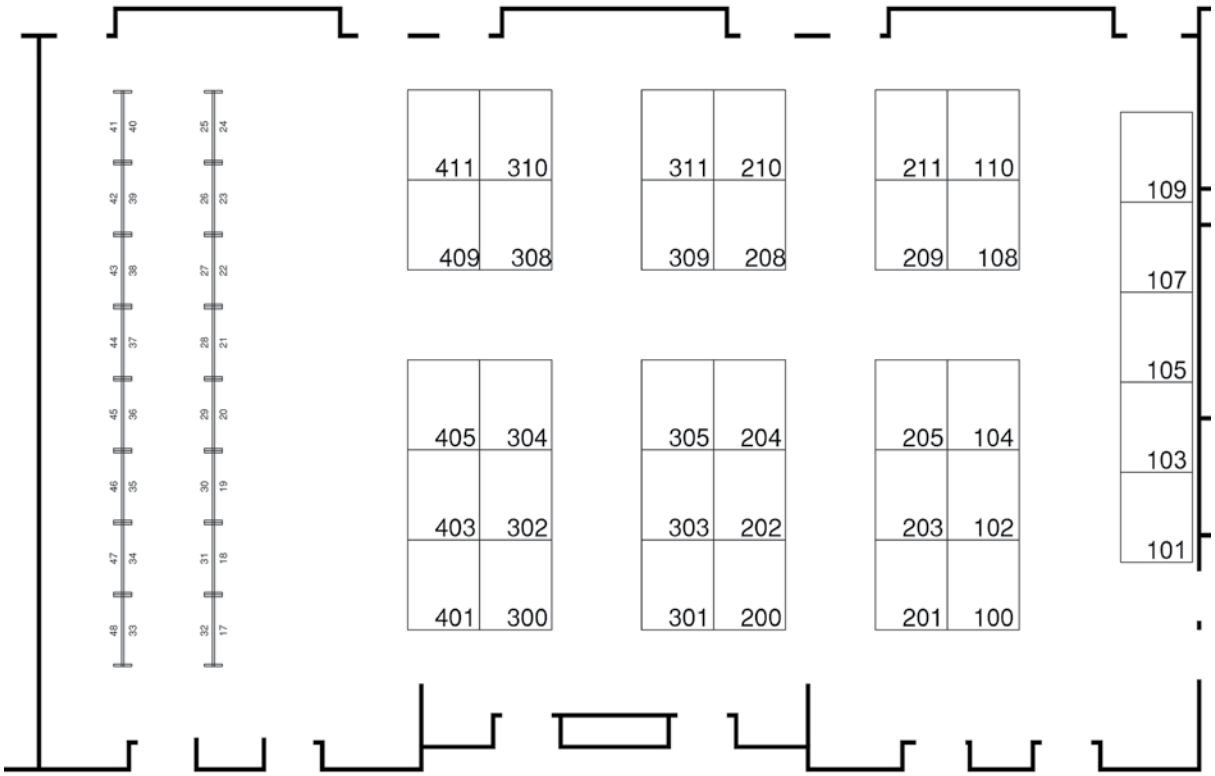
Exhibit Hall Hours

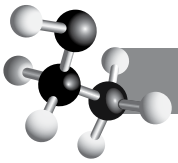
Location: Palms Ballroom

Sunday, June 4	**11:00 a.m.–3:00 p.m.**	Exhibitor Set-Up
	4:00–6:00 p.m.	Exhibits and Posters Opening Happy Hour
Monday, June 5	**12:30–2:30 p.m.**	Exhibits, Posters, and Lunch
Tuesday, June 6	**11:30 a.m.–1:30 p.m.**	Exhibits, Posters, and Lunch
	1:30–4:00 p.m.	Exhibitor Move-Out

Numerical Exhibitor Listing

Booth	Company
100	GEA Group
101	Anton Paar USA
102	Rheonix, Inc.
103	Charm Sciences, Inc.
104	Weber Scientific
105	DSM Food Specialties USA, Inc.
107	K&G Data Solutions
108	Pentair
109	TÜV Rheinland of North America
110	LGC Standards
200	ATPGroup Inc.
201	optek-Danulat, Inc.
203	Hygiena
204	Profamo Inc.
205	Bruker BioSpin
209	Gusmer Enterprises
208	Thermo Fisher Scientific
210	Whatman Inc.— GE Healthcare LS
211	Gerstel, Inc.
300	Amoretti
301	Pall Corporation
302	InnovaPrep
303	Hach
304	BMT USA, LLC
305	Kimble Chase Life Science
308	Astoria-Pacific
309	Lallemand Brewing
310	Air Science USA, LLC
311	Siebel Institute of Technology
401	Invisible Sentinel
403	Nexcelom Bioscience
405	HunterLab
409	Skalar, Inc.
411	Analytical Flavor Systems/ Gastrograph





Exhibitor Descriptions

Visit the exhibit hall to discover the latest products and services advancing the work of the industry. Meet the representatives to share the most up-to-date information and answer your questions. *Indicates Corporate Member

310 **Air Science USA, LLC**, 120 6th Street, Fort Myers, FL 33907, U.S.A.; Telephone: 1.800.306.0656; Fax: 1.800.306.0677, Web: www.airscience.com, E-mail: info@airscience.com. U.S.-based manufacturer of ductless and ducted fume hoods, laminar flow workstations, and custom enclosures to fit your needs. We also provide carbon and HEPA filters for our products as well as other major brands.

300 **Amoretti**, 451 Lombard Street, Oxnard, CA 93030 U.S.A.; Telephone: 1.855.855.3505, Web: www.amoretti.com, E-mail: brewers@amoretti.com, Facebook: www.facebook.com/amorettifoods, Twitter: @AmorettiFoods. Amoretti is the largest natural infusion and craft puree manufacturer in the U.S.A. For over 27 years, Amoretti has sourced the freshest fruits, herbs, and spices from around the world, paying meticulous attention to quality and consistency to create over 2,000 of the finest natural infusions for handcrafted beer.

411 **Analytical Flavor Systems/Gastrograph**, 119 W 24th Street, Floor 4, New York, NY 10011 U.S.A.; Telephone: +1.305.794.8392, Web: gastrograph.com, E-mail: jasonceo@gastrograph.com, Facebook: www.facebook.com/Gastrograph, Twitter: @Gastrograph. Gastrograph AI is the first artificial intelligence platform for the food and beverage industry that understands what consumers taste. Our platform makes predictions that optimize every step in a product's lifecycle, from conception to consumption.

101 ***Anton Paar USA**, 10215 Timber Ridge Drive, Ashland, VA 23005 U.S.A.; Telephone: +1.804.550.1051, Fax: +1.804.550.1051, Web: www.anton-paar.com, E-mail: lillianne.hall@anton-paar.com, Facebook: www.facebook.com/AntonPaarUSA, Twitter: #WhatsAPNews. Anton Paar USA is a leading supplier of instrumentation for key analytical parameters with over 30 years of experience and many long-term partnerships with the biggest names in the craft beverage industry. Precisely determine and monitor the alcohol content and numerous other quality parameters in wine, beer, spirits, and countless more.

308 **Astoria-Pacific**, PO Box 830, Clackamas, OR 97015 U.S.A.; Telephone: 1.800.536.3111, Web: www.astoria-pacific.com, E-mail: sales@astoria-pacific.com. Astoria-Pacific is pleased to offer a fully automated analyzer for total sulfite and primary amino nitrogen (NOPA). The rAPID-T is reliable, durable, and AFFORDABLE—for not only large-scale production facilities but also small- to medium-sized breweries as well. Please swing by our booth. Cheers!

200 ***ATPGroup Inc.**, 2 Madison Avenue, Suite 210, Larchmont, NY 10538, U.S.A.; Telephone: +1.914.834.1881, Web: www.atpgroup.com, E-mail: atpbeer@atpgroup.com. ATPGroup Inc. has a division dedicated to the brewing industry. We proudly present a wide product range that includes processing aids, anti-foams, cartridges and housings, clarifiers/stabilizers, enzymes, yeasts, filtration aids (cellulose, DE, Perlite), filter sheets, filtration equipment, glassware, packaging equipment, analytical equipment, and more. ATP represents well-respected and established companies such as Alfatek, Ajinomoto, Ashland, Eaton/Begerow, Birko, EP Minerals, Fermentis, Padovan, SPX, Stölzle, and WeissBiotech.

304 **BMT USA, LLC**, 14532 169th Drive SE, Ste 142, Monroe, WA 98272, U.S.A.; Telephone: +1.360.863.2252, Fax: +1.360.863.2366, Web: www.bmtus.com, E-mail: jeffh@bmtus.com, Facebook: www.facebook.com/BMTUSALLC. BMT USA is the premier supplier of clean steam generators utilized for the sterilization of kegs. Available in electric or steam-to-steam designs with capacities from 50 to 5,000 lb/hr. BMT USA also provides incubators and autoclaves for the QC lab. BMT USA—Assuring your quality.

205 **Bruker BioSpin**, 15 Fortune Drive, Billerica, MA 01821, U.S.A.; Telephone: +1.978.667.9580, Web: www.bruker.com, E-mail: marcom-bbio@bruker.com, Facebook: www.facebook.com/bruker.corp, Twitter: @bruker. For more than 50 years, Bruker has provided the best technological solutions for each analytical task. Bruker systems cover a broad spectrum of applications in all fields of research and development and are used in all industrial production processes for the purpose of ensuring quality and process reliability.

103 **Charm Sciences, Inc.**, 659 Andover Street, Lawrence, MA 01843 U.S.A.; Telephone: +1.978.687.9200, Web: www.charm.com, E-mail: info@charm.com, Facebook: www.facebook.com/charmsciencesinc, Twitter: @CharmSciences. Charm Sciences is a world leader of food safety diagnostics. Charm's portfolio includes tests for mycotoxins (e.g., DON or vomitoxin), ATP sanitation verification, and microbial detection to assess beer quality. Rely on Charm for excellence in quality, innovation, and sensitivity to protect your brand.

105 **DSM Food Specialties USA, Inc.**, 3502 N. Olive Road, South Bend, IN 46628, U.S.A.; Telephone: +1.574.237.6974, Web: www.dsm.com/food, E-mail: camilo.parris@dsm.com, Facebook: www.facebook.com/DSMcompany, Twitter: @DSM. DSM Food Specialties offers a range of brewing enzymes and support from our global team of brewmasters. Gain maximum control over your production processes, improve brewing efficiency, and deliver consistently clear, higher quality beer at a lower cost.

100 **GEA Group**, 9165 Rumsey Road, Columbia, MD 21045 U.S.A.; Telephone: 1.844.432.2329, Telephone 2: +1.845.384.9200, Web: www.gea.com, E-mail: sales.unitedstates@gea.com. The GEA portfolio includes over 50 solutions developed to meet the needs of today's brewers. At GEA Group, we can design and engineer turnkey breweries and also provide individual solutions and components to enhance the performance of existing operations. Our wide range of products is supported by a superior service commitment.

211 **Gerstel, Inc.**, 701 Digital Drive, Suite J, Linthicum, MD 21090, U.S.A.; Telephone: +1.410.247.5885, Telephone 2: 1.800.413.8160, Fax: +1.410.247.5885, Web: www.gerstelus.com, E-mail: internalsales@gerstelus.com, Facebook: www.facebook.com/GERSTELUS, Twitter: @GERSTEL_USA. 50 years of chemical analysis solutions: since 1967, Gerstel analytical instrumentation has enabled analysts to achieve ultra-low detection levels in complex matrices with unequalled preparative capability while dramatically increasing sample throughput, handle difficult sample preparation challenges, and analyze a wide range of sample types complete with software integration (Agilent Technologies, SCIEX, LECO, Thermo Fisher Scientific, Shimadzu). Gerstel is the world's largest partner of Agilent Technologies for customer oriented GCMS and LCMS solutions.

209 ***Gusmer Enterprises**, 1165 Globe Avenue, Mountainside, NJ 07092, U.S.A.; Telephone: +1.908.301.1811, Fax: +1.908.301.1812, Web: www.gusmerbeer.com, E-mail:sales@gusmerenterprises.com, Facebook:www.facebook.com/gusmerenterprises, Twitter: @gusmerbeer. For over 90 years, Gusmer has taken a revolutionary approach to serving the brewer's vision. It's why Gusmer offers a full line of solutions for the brewing industry including fermentation and processing aids, filtration media and equipment, analytical products and instrumentation, processing equipment, and analytical laboratory services.

303 ***Hach**, 5600 Lindbergh Drive, Loveland, CO 80538, U.S.A.; Telephone: +1.970.663.1377, Web: www.hach.com, Facebook: www.facebook.com/HachCompany, Twitter: @HachCompany. Hach has been helping the brewing industry for over 70 years. We know that quality is key. It matters not just at the end of your line, but, more importantly, when and where your customer takes their first sip. As a craft brewer flavor, stability, and shelf life are critical to your brand and your overall business.

405 **HunterLab**, 11491 Sunset Hills Road, Reston, VA 20190 U.S.A.; Telephone: +1.703.471.6870, Web: hunterlab.com, E-mail: info@hunterlab.com, Facebook: www.facebook.com/HunterLab, Twitter: @Hunterlab. HunterLab is your premier choice for color measurement solutions, providing both ASBC Beer Color and ASBC Turbidity scales in our color measurement software. Combined with our UltraScan VIS and Vista spectrophotometers, HunterLab is the finest solution for your color measurement challenges.

203 ***Hygiena**, 941 Avenida Acaso, Camarillo, CA 93012, U.S.A.; Telephone: 1.888.HYGIENA, Web: hygiena.com, E-mail: info@hygiena.com, Twitter: @HygienaUSA. Recognized worldwide for accuracy, ease of use, and affordability, Hygiena's ATP Sanitation Monitoring System is used extensively throughout beverage industries to validate sanitation protocols and determine whether equipment is truly clean. The EnSURE™ Monitoring System measures ATP from surface and liquid samples.

302 **InnovaPrep**, 132 East Main Street, Drexel, MO 64742, U.S.A.; Telephone: +1.816.619.3375, E-mail: info@innovaprep.com, Facebook: www.facebook.com/InnovaPrep-141690452519415. InnovaPrep provides tools for effortless and rapid sample preparation and concentration of spoilage organisms in large dilute volumes of beer in minutes. This technology enables cutting-edge detection instruments to contribute their full potential for same day results. Please visit our booth for a demonstration of the InnovaPrep Concentrating Pipette—the first truly automated sample concentrator. Also, see our new hands-off beer degassing kit for faster sampling!

401 **Invisible Sentinel**, 3711 Market Street, Suite 910, Philadelphia, PA 19104, U.S.A.; Telephone: +1.215.966.6118, Fax: +1.215.921.5091, Web: invisiblesentinel.com, E-mail: jerm0203@yahoo.com, Twitter: @Invisible_Sntl. Invisible Sentinel's suite of rapid detection tools for the brewing industry provide brewers with a proactive method to protect their beer quality via same-day detection of spoilage organisms at any stage of production and in any style of beer. Powered by Veriflow®—a proprietary, game-changing PCR technology, and validated and implemented by a variety of award winning, quality-centric breweries around the world.

107 ***K&G Data Solutions**, 38 East Ridgewood Ave, #272, Ridgewood, NJ 07450, U.S.A.; Telephone: 1.844.310.1641, Web: www.brew-q.com, E-mail: info@kgdatasolutions.com, Facebook: www.facebook.com/kgdatasolutions, Twitter: @kgdatasolutions. K&G Data Solutions provides Brew-Q, a software that collects, analyzes, and reports on quality data for breweries of all sizes.

305 ***Kimble Chase Life Science**, 234 Cardiff Valley Road, Rockwood, TN 37854, U.S.A.; Telephone: +1.865.717.2600, Web: www.kimble-chase.com, E-mail: r.toth@kimblechase.com. Kimble Chase Life Science manufactures quality lab glassware and is a supporter of quality beer making. We have partnered with ASBC in developing kits for the ASBC Methods on beer bitterness and total acidity. Everything you need, including the method instructions. A portion of all kit sales goes back to ASBC to support this great organization.

309 **Lallemand Brewing,** 6210 W Douglas Ave, Milwaukee, WI 53218, U.S.A.; Telephone: +1.702.202.7233, Web: www.lallemandbrewing.com, E-mail: brewing@lallemand.com. Lallemand Brewing is a global leader in the development, production, and marketing of yeast, bacteria, and other microorganisms. Products and services include premium brewing yeasts and bacteria, the AB Vickers' line of process aids, and the whole range of educational and microbiological services provided by the Siebel Institute of Technology.

110 **LGC Standards**, 276 Abby Road, Manchester, NH 03103, U.S.A.; Telephone: +1.603.622.7660, Fax: +1.603.622.5180, Web: www.lgcstandards.com. LGC Standards is an ISO accredited provider of proficiency testing services and manufacturer of certified reference materials to more than 10,000 laboratories worldwide. Our beverage PTs include those for brewing analytes, malt analytes, and alcoholic drinks. We provide CRMs for beer, wine, and alcoholic and non-alcoholic beverages.

403 **Nexcelom Bioscience**, 360 Merrimack Street, Building 9, Lawrence, MA 01843, U.S.A.; Telephone: +1.978.327.5340, Fax: +1.978.327.5341, Web: www.nexcelom.com/cellometer-x2, E-mail: info@nexcelom.com, Facebook: www.facebook.com/nexcelom, Twitter: @Nexcelom. Nexcelom's Cellometer X1/X2 image cytometers are simple-to-use cell counters optimized for yeast samples, automating cell counting procedures by obtaining accurate counts, viability, and cell size in less than 30 seconds and only 20uL of sample. Fluorescence detection capabilities enable fast and simple determination of viability and vitality for brewing fermentation.

201 ***optek-Danulat, Inc.**, N118W18748 Bunsen Drive, Germantown, WI 53022, U.S.A.; Telephone: 1.888.837.4288, Web: www.optek.com, E-mail: brew@optek.com, Facebook: www.facebook.com/optek, Twitter: @optek. Inline photometers provide precise, real-time control for brewing optimization. Monitor color, haze, and yeast and solids concentration. Control fermentation, filtration, separation, yeast pitching, wort color and clarity, DE and PVPP dosing, and more. Achieve uninterrupted processing of your best possible product with reduced product loss, improved profitability, and greater efficiency.

301 ***Pall Corporation**, 25 Harbor Park Drive, Port Washington, NY 11050 U.S.A.; Telephone: 1.866.905.7255, Web: www.pall.com/foodandbev.

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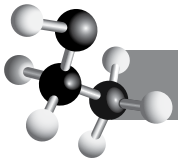

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