See what SCIENCE can brew for you.

2015 ASBC Annual Meeting

June 14–17 ■ La Quinta, CA

Program

ASBC is here for you!

More Science, More Tools, More Resources

ASBC can help you build your professional network, develop your skills, utilize SCIENCE-based approaches and solutions, and implement analytical, methods and procedures to ensure high quality and safety standards.

Take full advantage of all ASBC has to offer:

- *ASBC Methods of Analysis*
- Brewing and Scientific Books
- Check Sample Program
- *Journal of the ASBC* and *ASBC Buzz*
- *Fishbone References for Applied Brewing Scientists*
- Scientific Tools Including Crimp Bars and Analytical Standards
- Webinars

ASBC is your complete toolbox for quality brewing through science. If you're not a member, what are you waiting for…join today.

Visit **asbcnet.org** to see all this and MORE!

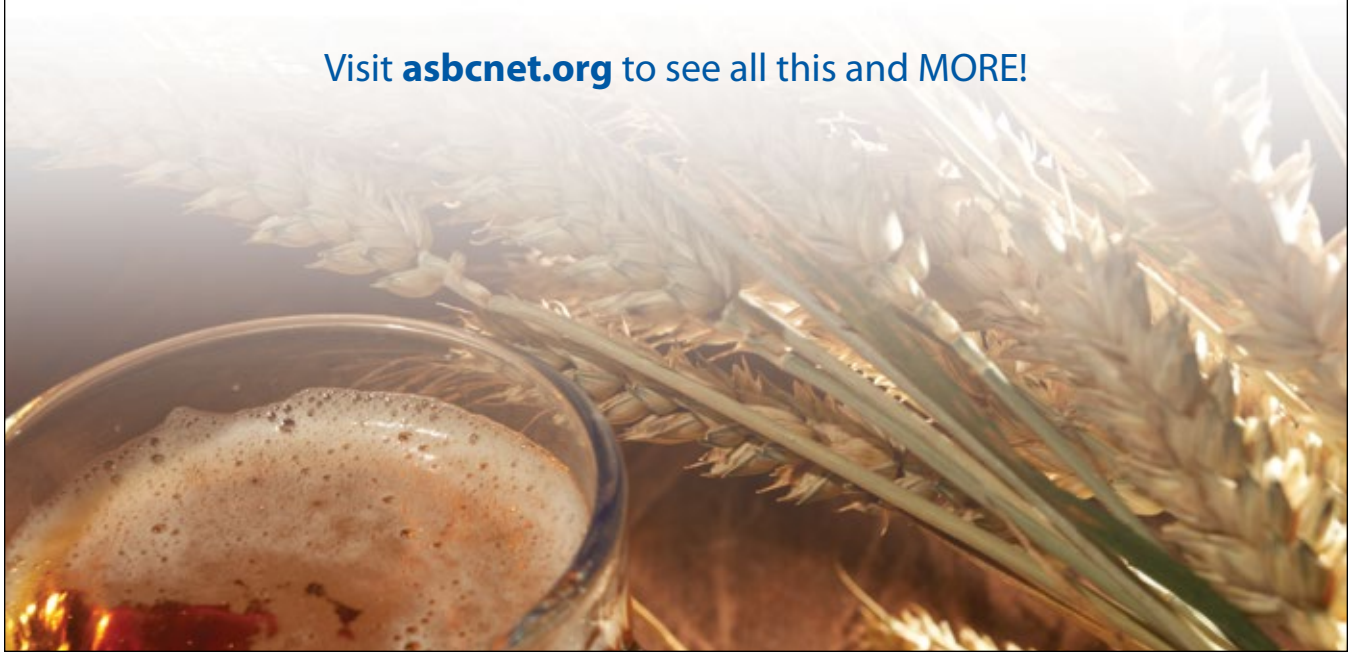


TABLE OF CONTENTS

2015
ASBC
Annual Meeting
June 14–17
La Quinta, California

Welcome from the Program Committee

Follow us on Twitter at #ASBC2015

Dear Attendees,

It is my extreme pleasure to welcome you to La Quinta, California, for the 2015 ASBC Annual Meeting: **see what SCIENCE can brew for you.** The Annual Meeting brings together professionals and students from around the world to advance their science, network, and careers.

The Program Committee has worked diligently this year to create a diverse and energizing program that will update your knowledge, broaden your skills, and challenge you to explore other arenas within the **SCIENCE OF BEER.**

The extensive selection of workshops, technical sessions, and special interest sessions will surely enlighten your mind. I encourage you to take advantage of the extended poster hours to view posters and discuss the great science being undertaken by our members. I also invite you to join me for the Opening Session and State of the Society Address at 8:30 a.m. on Sunday, where we will highlight ASBC's accomplishments over the past year and discuss some of our future initiatives. Immediately following will be keynote speaker, **Katherine Smart, (SABMiller PLC)**, who will discuss the contributions of brewers to some of the most impactful scientific discoveries in her talk entitled "Brewing Science—From Enviable Heritage to Impressive Future."

In addition to this year's keynote speaker, we are excited to debut an expanded list of guest speakers. Don't miss the thought-provoking presentations by **Chris Swersey (Brewers Association), Jennifer Jo Wiseman (E. & J. Gallo Winery),** and **Christina Schoenberger (Joh. Barth & Sohn GmbH & Co. KG)**.

Finally, have fun as you meet, connect, and enjoy a beer with your colleagues from around the world. I invite you to join me at the **Orientation and Molecular Mixer, "The Buzz" Happy Hour, Luminosity: Reception under the Stars,** and the **"Top Cosmos" Challenge**. After all, this meeting is about "brewing" up some good connections.

I look forward to seeing familiar faces, making new friends, and hearing about the most recent advances in brewing science in La Quinta! If you see me, please stop me to say "Hi."

Scott J. Britton
ASBC Program Committee Chair

SCHEDULE-AT-A-GLANCE

Saturday, June 13		
8:00 a.m.–5:00 p.m.	Board of Directors Meeting	*Las Brisas*
9:00 a.m.–12:00 p.m.	**Premeeting Workshop**: Quality Parameters for Freshness and Flavor	*Fiesta 14*
1:30–4:30 p.m.	**Premeeting Workshop**: Barrel Aging: Knock on Wood!	*Fiesta 14*
2:00–5:00 p.m.	Registration Desk Open	*The Studio*
5:30–6:00 p.m.	**Orientation and Molecular Mixer**	*Flores 2*
Sunday, June 14		
7:30–8:30 a.m.	Speakers' Breakfast	*Flores 1–2*
7:30 a.m.–5:00 p.m.	Registration Desk Open	*The Studio*
8:30–10:00 a.m.	**Opening Session and Keynote**: Brewing Science—From Enviable Heritage to Impressive Future	*Fiesta 3,4,6,8*
10:15 a.m.–12:00 p.m.	**Technical Session 1**: Sensory	*Fiesta 3,4,6,8*
10:15 a.m.–12:00 p.m.	**Workshop**: Statistical Process Control I	*Flores 1–2*
2:00–3:15 p.m.	**Technical Session 2**: Industrial Yeast Management	*Fiesta 3,4,6,8*
2:00–4:00 p.m.	**Special Interest Session**: The Journey from Tribal Knowledge to Solid Science: Building a Quality Program	*Flores 1–2*
4:00–6:00 p.m.	**Exhibits Opening**: **"The Buzz" Happy Hour**	*Fiesta 1,2,5,7,9,11,12*
4:00–6:00 p.m.	**Posters Opening**: **"The Buzz" Happy Hour**	*Fiesta 13–14*
Monday, June 15		
7:30 a.m.–5:00 p.m.	Registration Desk Open	*The Studio*
8:00 a.m.–5:00 p.m.	Poster Viewing Hours	*Fiesta 13–14*
8:30–10:15 a.m.	**Technical Session 3**: Hop Aroma	*Fiesta 3,4,6,8*
8:30–10:30 a.m.	**Workshop**: The Science Behind Packaging Quality	*Flores 1–2*
10:45 a.m.–12:00 p.m.	**Technical Session 4**: Flavor and Product Stability I	*Fiesta 3,4,6,8*
10:45 a.m.–12:00 p.m.	**Technical Session 5**: Foam	*Flores 1–2*
12:00–2:00 p.m.	Exhibits and Lunch	*Fiesta 1,2,5,7,9,11,12*
2:00–3:45 p.m.	**Technical Session 6**: Yeast and Microbiology	*Flores 1–2*
2:00–4:00 p.m.	**Special Interest Session**: State of the Hop Industry	*Fiesta 3,4,6,8*
4:15–5:00 p.m.	**Guest Speaker Session**: Why Should Anyone Care About Quality Beer?	*Fiesta 3,4,6,8*
6:30–9:30 p.m.	**Luminosity: Reception under the Stars**	*La Casa Complex*

Tuesday, June 16		
8:00 a.m.–5:00 p.m.	Registration Desk Open	*The Studio*
8:00 a.m.–1:30 p.m.	Poster Viewing Hours	*Fiesta 13–14*
8:30–10:15 a.m.	**Technical Session 7**: Malt and Grain	*Fiesta 3,4,6,8*
8:30–10:15 a.m.	**Workshop**: Statistical Process Control II	*Flores 1–2*
10:30–11:30 a.m.	**Special Interest Session**: Dry Hop Aroma in Beer—A Review	*Fiesta 3,4,6,8*
11:30 a.m.–1:30 p.m.	Exhibits and Lunch	*Fiesta 1,2,5,7,9,11,12*
1:30–3:15 p.m.	**Technical Session 8**: Methods of Analysis	*Fiesta 3,4,6,8*
1:30–3:30 p.m.	**Workshop**: What's the Difference? Understanding and Selecting Sensory Difference Test Methods	*Flores 1–2*
3:15–3:45 p.m.	**New and Alternate *Methods of Analysis***	*Fiesta 3,4,6,8*
Wednesday, June 17		
8:30 a.m.–3:00 p.m.	Registration Desk Open	*The Studio*
8:30–10:15 a.m.	**Technical Session 9**: Hop Flavor and Analytics	*Fiesta 13–14*
8:30–10:30 a.m.	**Special Interest Session**: Science of Sour Beer	*Fiesta 3,4,6,8*
10:40–11:40 a.m.	**Special Interest Session**: "I've Always Wanted to Know..."	*Fiesta 3,4,6,8*
1:00–2:15 p.m.	**Technical Session 10**: Fermentation	*Fiesta 13–14*
1:00–2:15 p.m.	**Technical Session 11**: Flavor and Product Stability II	*Fiesta 3,4,6,8*
2:30–4:00 p.m.	**Closing Session with Guest Speaker**: Sensory Thinking: An Essential Element to Innovation	*Fiesta 3,4,6,8*
4:00–5:00 p.m.	**"Top Cosmos" Challenge**	*Hotel Waterfall*

SPONSORS

ELITE

DUPONT®

novozymes®
Rethink Tomorrow

PREMIER

Cargill®

CONTRIBUTING

ERA
A Waters Company

BEER SPONSORS

ALLAGASH BREWING COMPANY

Asahi

BELL'S Inspired Brewing

SAMUEL ADAMS

BOULEVARD BREWING CO.

DESCHUTES BREWERY

Estrella Damm Barcelona 1876

FIRESTONE WALKER BREWING COMPANY

KARL STRAUSS BREWING COMPANY

KIRIN

KONA BREWING CO.

La Quinta Brewing Co.

MillerCoors

NEW BELGIUM BREWING

Omission

Orion

RED HOOK

SAPPORO

SIERRA NEVADA

STONE BREWING CO.

SUMMIT BREWING CO.

SUNTORY

WIDMER BROTHERS BREWING

GENERAL INFORMATION

Registration Hours

Location: The Studio

Saturday, June 13 ..... 2:00–5:00 p.m.

Sunday, June 14 .....7:30 a.m.–5:00 p.m.

Monday, June 15 .....7:30 a.m.–5:00 p.m.

Tuesday, June 16 ..... 8:00 a.m.–5:00 p.m.

Wednesday, June 17 ..... 8:30 a.m.–3:00 p.m.

Please have your name badge with you at all times to ensure access to sessions and events.

Hospitality Room Hours

Location: Diego Rivera Room

Saturday, June 13 ..... 3:00–11:00 p.m.

Sunday, June 14 ..... 6:00–11:00 p.m.

Monday, June 15 ..... 5:00–6:30 p.m.
9:00–11:00 p.m.

Tuesday, June 16 ..... 5:00–11:00 p.m.

Wednesday, June 17 ..... 5:00–11:00 p.m.

Guests

Guests wishing to attend the Luminosity Reception must purchase a ticket to attend. Guests do not have access to the technical program 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 Subcommittee Meetings

Attend any of the technical subcommittee meetings held throughout the annual meeting and help ensure the ongoing quality of the *ASBC Methods of Analysis*. Each meeting is specific to a technical subcommittee run from 2014–2015 and will provide an overview of the committee's results and recommendations. The meetings are open to all, and your feedback and participation are essential to the methods program. Check the addendum for subcommittee meetings.

Speaker Kiosk

The speaker kiosk will be available for speakers to review their presentations the day before their scheduled session. The kiosk is located near the Registration Desk.

Photo Release

Photographs will be taken at the 2015 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

Saturday, June 13

8:00 a.m.–5:00 p.m.	Board of Directors Meeting	*Las Brisas*
9:00 a.m.–12:00 p.m.	**Premeeting Workshop**: Quality Parameters for Freshness and Flavor	*Fiesta 14*
1:30–4:30 p.m.	**Premeeting Workshop**: Barrel Aging: Knock on Wood!	*Fiesta 14*
2:00–5:00 p.m.	Registration Desk Open	*The Studio*
3:00–11:00 p.m.	Hospitality Room Open	*Diego Rivera Room*
5:30–6:00 p.m.	**Orientation and Molecular Mixer**	*Flores 2*

Saturday Highlights

Premeeting Workshop: Quality Parameters for Freshness and Flavor

9:00 a.m.–12:00 p.m. • Fiesta 14

Aaron MacLeod, Canadian Grain Commission; Lauren Zeidler, Ballast Point Brewing Co.; Jessica Davis, The Bruery

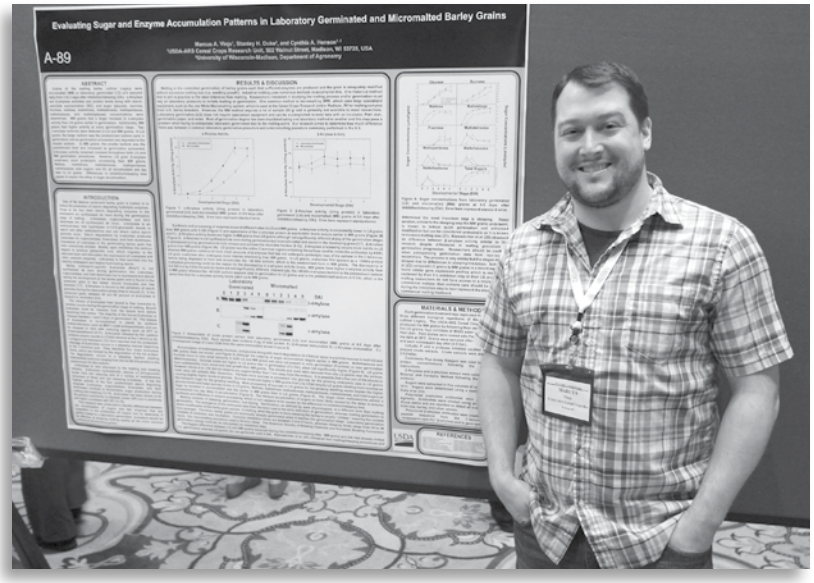
In this workshop, brewers will get great insight on moving quality to the forefront with limited resources, especially in breweries undergoing rapid expansion. What would experts do to create the best quality program to support freshness and flavor? Find out the key metrics for sensory, micro, and analysis that provide an edge to freshness and flavor so your beer is not tortured before it leaves the brewery.

Premeeting Workshop: Barrel Aging: Knock on Wood!

1:30–4:30 p.m. • Fiesta 14

Gwen Conley, Port Brewing Co., Lost Abbey; Christine Hansen, E. & J. Gallo Winery

How does a brewer create a barrel age program for consistency? This workshop will cover barrel sampling, barrel micro, barrel genealogy (wood type, previous fill), flavor impacts, and gains from barrel aging. What are the decisions for best beer production? Keep it to the Science of Beer and understand what is required to be successful. Can consistency be gained, can micro be controlled, and is sampling "secret" or are there parameters for best selection?



Sunday, June 14

7:30–8:30 a.m.	Speakers' Breakfast	*Flores 1–2*
7:30 a.m.–5:00 p.m.	Registration Desk Open	*The Studio*
8:30–10:00 a.m.	**Opening Session and Keynote: Brewing Science—From Enviable Heritage to Impressive Future**	*Fiesta 3,4,6,8*
10:15 a.m.–12:00 p.m.	**Technical Session 1: Sensory**	*Fiesta 3,4,6,8*
	Moderator: Cindy-Lou Lakenburges, Anheuser-Busch, LLC	
	10:15 a.m. 1. L. Guerdrum. A contemporary tool for a new age in brewing: Bringing modern science into everyday flavor analysis	
	10:40 a.m. 2. J. Hort. Measuring the emotional response to beer: The long and the short of it!	
	11:05 a.m. 3. B. Gadzov. Beer quality and stability on the market	
	11:30 a.m. 4. A. G. Barlow. New methods of sensory evaluation: Their implications and applications for drinkability assessment and beer–food pairing based upon statistical and consumer studies	
10:15 a.m.–12:00 p.m.	**Workshop: Statistical Process Control I**	*Flores 1–2*
2:00–3:15 p.m.	**Technical Session 2: Industrial Yeast Management**	*Fiesta 3,4,6,8*
	Moderator: Xiang Yin, SABMiller PLC	
	2:00 p.m. 5. A. R. Bhat. Evaluating a portable yeast pitching skid for reliable and accurate pitching for craft breweries	
	2:25 p.m. 6. K. M. Thomson. Practical experiences with an automated yeast cell counter using methylene blue in breweries	
	2:50 p.m. 7. L. L. Chan. Rapid yeast viability detection method in complex brewing samples using the Cellometer X2 image cytometry	
2:00–4:00 p.m.	**Special Interest Session: The Journey from Tribal Knowledge to Solid Science: Building a Quality Program**	*Flores 1–2*
4:00–6:00 p.m.	**Exhibits Opening: "The Buzz" Happy Hour**	*Fiesta 1,2,5,7,9,11,12*
4:00–6:00 p.m.	**Posters Opening: "The Buzz" Happy Hour**	*Fiesta 13–14*
6:00–11:00 p.m.	Hospitality Room Open	*Diego Rivera Room*

Sunday Highlights

Opening Session and Keynote: Brewing Science—From Enviable Heritage to Impressive Future

8:30–10:00 a.m. • Fiesta 3,4,6,8

Katherine Smart, SABMiller PLC

Brewing can be considered to be the most interesting combination of art, skill, technology, engineering, and science. Despite this, brewers are seldom given credit for their contributions to novel scientific discovery, despite an enviable heritage in this regard. During this presentation, the impact of brewers on some of the most important historical scientific discoveries will be discussed. Many eminent scientists have been attracted to and intrigued by key brewing challenges and this presentation will explore what future challenges drive these individuals towards our sector. Insights into the future of brewing science and engineering will be discussed.

Workshop: Statistical Process Control I

10:15 a.m.–12:00 p.m. • Flores 1–2

Gina Shellhammer, GSJ Consulting

Learn to define and calculate standard deviation, explain the connection between the central limit theorem and the use of normal distribution in control charting, and differentiate between common and assignable cause. This workshop is geared toward beginners and novices who want to learn more about process control and statistics. At the conclusion of this workshop, you will learn how to construct a control chart utilizing Excel, describe how changes in mean and variation affect a control chart, predict the effect of different sampling plans when assignable cause variation is present, and be able to modify your control chart for varying sampling sizes.

Special Interest Session: The Journey from Tribal Knowledge to Solid Science: Building a Quality Program

2:00–4:00 p.m. • Flores 1–2

Eric Jorgenson, Highland Brewing; Ben Chambers, Ninkasi Brewing Co.; Karen Fortmann, White Labs; Aaron Golston, Lagunitas Brewing Co.; Christine Hansen, E. & J. Gallo Winery

Many of our new and expanding breweries are coming from the success of making great beer, and consumer demand has defined their quality. Looking ahead as a brewery grows, how will a brewer move from tribal knowledge to creating a robust quality program? Can a brewery move from quality control through quality assurance to achieve quality improvement and innovation with ease and understanding? This session provides insight into how and who at the breweries are making those quality programs happen. It's all about the science of beer!

Exhibits and Posters Opening: "The Buzz" Happy Hour

4:00–6:00 p.m. • Fiesta 1,2,5,7,9,11,12 and Fiesta 13–14

Don't miss the Exhibit and Poster Grand Opening. It's your opportunity to spend valuable time with industry suppliers and poster presenters to exchange ideas, expand your knowledge, and, most importantly, make rewarding connections. Of course, take advantage of "The Buzz" Happy Hour with beer and light snacks. It's sure to be an effervescent event.

Monday, June 15

7:30 a.m.–5:00 p.m.	Registration Desk Open	*The Studio*
8:00 a.m.–5:00 p.m.	Poster Viewing Hours	*Fiesta 13–14*
8:30–10:15 a.m.	**Technical Session 3: Hop Aroma**	*Fiesta 3,4,6,8*
	Moderator: Patricia Aron, MillerCoors	
	8:30 a.m. 8. D. C. Sharp. Contributions from the β-glucosidase activity of brewing yeast to hoppy beer aroma	
	8:55 a.m. 9. T. Praet. Sesquiterpene oxidation products as key impact compounds for "kettle hop" aroma	
	9:20 a.m. 10. D. M. Vollmer. The influence of oil content on aroma in beer dry-hopped with Cascade	
	9:45 a.m. 11. J. Wei. Measurement of terpene alcohols and their stereoisomers in beer and the applications for improving beer hop aroma	
8:30–10:30 a.m.	**Workshop: The Science Behind Packaging Quality**	*Flores 1–2*
10:45 a.m.–12:00 p.m.	**Technical Session 4: Flavor and Product Stability I**	*Fiesta 3,4,6,8*
	Moderator: Aaron Golston, Lagunitas Brewing Co.	
	10:45 a.m. 12. A. L. Heuberger. Non-volatile metabolites associated with flavor stability in beer	
	11:10 a.m. 13. N. Doi. What compound is primarily responsible for the metallic flavor in beer?	
	11:35 a.m. 14. N. Rettberg. Permeation of volatile organic compounds into packaged beer—Tools for practice oriented simulation and analysis	
10:45 a.m.–12:00 p.m.	**Technical Session 5: Foam**	*Flores 1–2*
	Moderator: Dana Sedin, New Belgium Brewing Co.	
	10:45 a.m. 15. Y. Katayama. Improvement of wort foam stability by yeast-derived substances	
	11:10 a.m. 16. C. Neugrodda. Influence of hop products and natural foam enhancer on beer foam	
	11:35 a.m. 17. Y. Zhou. The influence of beer protein components and content on beer colloidal and foam quality	
12:00–2:00 p.m.	Exhibits and Lunch	*Fiesta 1,2,5,7,9,11,12*
12:30–1:30 p.m.	Poster Authors Present	*Fiesta 13–14*
	12:30–1:00 p.m. Odd-numbered poster authors at poster	
	1:00–1:30 p.m. Even-numbered poster authors at poster	
2:00–3:45 p.m.	**Technical Session 6: Yeast and Microbiology**	*Flores 1–2*
	Moderator: Karen Fortmann, White Labs	
	2:00 p.m. 18. T. Kato. Fermentation ability of bottom fermenting yeast exhibiting defective entry into the quiescent state	
	2:25 p.m. 19. J. Bergsveinson. Search for genetic markers for lactic acid bacteria beer-spoilage and the role of dissolved CO_2/pressure on bacterial growth in beer	
	2:50 p.m. 20. C. Schoenberger. Gushing Task Force: Round table on "primary gushing"	
	3:15 p.m. 21. C. Geissinger. *Fusarium* species on barley malt—Visual assessment as an appropriate tool?	
2:00–4:00 p.m.	**Special Interest Session: State of the Hop Industry**	*Fiesta 3,4,6,8*
4:15–5:00 p.m.	**Guest Speaker Session: Why Should Anyone Care About Quality Beer?**	*Fiesta 3,4,6,8*
5:00–6:30 p.m.	Hospitality Room Open	*Diego Rivera Room*
6:30–9:30 p.m.	**Luminosity: Reception under the Stars**	*La Casa Complex*
9:00–11:00 p.m.	Hospitality Room Open	*Diego Rivera Room*

Monday Highlights

Workshop: The Science behind Packaging Quality

8:30–10:30 a.m. • Flores 1–2

Lauren Torres, Bell's Brewery; Scott Brendecke, Ball Corporation

Shadow the process of beer packaging from the manufacturing facility to the consumer. Discover the science behind how storage of empty packages, seaming of can-ends, crowning of bottles, and filling affect the flavor of your product. Learn to recognize what steps should be followed and to quantify how you can minimize oxidative flavor changes.

Special Interest Session: State of the Hop Industry

2:00–4:00 p.m. • Fiesta 3,4,6,8

Michael Roy, Roy Farms, Inc.; Jason Perrault, Perrault Farms, Inc.; Patricia Aron, MillerCoors; Christina Schoenberger, Joh. Barth & Sohn GmbH & Co. KG; Tim Kostelecky, John I Haas Inc.

As the craft beer industry matures and grows horizontally, the supporting hop industry is adapting to support the market needs. This session will provide insight into the hop industry at many different levels. Featured speakers will discuss the state of the world hop market, advancements in hop breeding, improvements in sustainability, and advancements in hop agronomics, as well as industry hop usage and the hop flavor impact paradigm.

Guest Speaker Session: Why Should Anyone Care About Quality Beer?

4:15–5:00 p.m. • Fiesta 3,4,6,8

Chris Swersey, Brewers Association

Today's alcohol drinker has more beverage type and brand choices than ever before. Competition for share of stomach and share of dollars means that only the strongest will survive; brewers who ignore customer expectations do so at their peril. Fulfilling drinker quality expectations is essential for the long-term health of beer as a beverage and for individual beer brands. Brewers large and small have unique needs and means of satisfying those expectations. Communicating the quality imperative to motivate brewers and providing the right tools to help individual brewers measure quality progress are critical to keeping beer, breweries, and their brands competitive. Chris Swersey, technical brewing projects manager and competition manager for the Brewers Association, will address the craft brewer mindset, identity, and needs as they pertain to overall beer quality.

Luminosity: Reception under the Stars

6:30–9:30 p.m. • La Casa Terrace

Sponsored in part by Du Pont.

Enjoy a brilliant evening under the stars at the historic La Quinta Resort. The Luminosity Reception will take place at the La Casa outside terrace overlooking the picturesque Santa Rosa Mountains. Relax, drink, eat, and reflect on all the enlightening content of the past couple days with colleagues and friends.

Tuesday, June 16

8:00 a.m.–5:00 p.m.	Registration Desk Open	*The Studio*
8:00 a.m.–1:30 p.m.	Poster Viewing Hours	*Fiesta 13–14*
8:30–10:15 a.m.	**Technical Session 7: Malt and Grain** *Moderator: Rebecca Jennings, Rahr Malting Co.* 8:30 a.m. 22. C. L. Almaguer. From raw materials to malts: Influence of the malting parameters on malt aroma development 8:55 a.m. 23. D. W. Herb. Barley contributions to beer flavor I: Effect of variety, location, and genotype × environment interaction on beer flavor 9:20 a.m. 24. C. I. Nnamchi. Influence of added commercial enzyme preparations and mashing temperature on extract recovery of laboratory malted Nigerian grown pearl millet and wheat 9:45 a.m. 25. K. L. Christiansen. Overcoming pre-harvest sprout damaged malt: The effects of enzyme addition	*Fiesta 3,4,6,8*
8:30–10:15 a.m.	**Workshop: Statistical Process Control II**	*Flores 1–2*
10:30–11:30 a.m.	**Special Interest Session: Dry Hop Aroma in Beer— A Review**	*Fiesta 3,4,6,8*
11:30 a.m.–1:30 p.m.	Exhibits and Lunch	*Fiesta 1,2,5,7,9,11,12*
12:00–1:00 p.m.	Poster Authors Present 12:00–12:30 p.m. Even-numbered poster authors at poster 12:30–1:00 p.m. Odd-numbered poster authors at poster	*Fiesta 13–14*
1:30–3:15 p.m.	**Technical Session 8: Methods of Analysis** *Moderator: Aaron MacLeod, Canadian Grain Commission* 1:30 p.m. 26. D. Sedin. Development of a GC method for the analysis of twelve key fermentation derived volatiles utilizing deuterated internal standards, SPME, and SIM 1:55 p.m. 27. C. A. Hughey. Beeromics: From QC to IDs of differentially expressed compounds 2:20 p.m. 28. A. R. Spevacek. NMR metabolomics reveals molecular details of the brewing process 2:45 p.m. 29. F. Verkoelen. The evolution of CO_2 measurement within the brewing industry: What does it bring to breweries and what will be the next step?	*Fiesta 3,4,6,8*
1:30–3:30 p.m.	**Workshop: What's the Difference? Understanding and Selecting Sensory Difference Test Methods**	*Flores 1–2*
3:15–3:45 p.m.	**New and Alternate *Methods of Analysis***	*Fiesta 3,4,6,8*
5:00–11:00 p.m.	Hospitality Room Open	*Diego Rivera Room*

Tuesday Highlights

Workshop: Statistical Process Control II

8:30–10:15 a.m. • Flores 1–2

Gina Shellhammer, GSJ Consulting; Paul Pettinger, New Belgium Brewing Co.; Eric Samp, MillerCoors

Process control is the next frontier in a QA/QC program. Understanding variation in your process from a raw material and equipment perspective can provide insight into issues before they happen. This workshop is geared toward those already with a basic knowledge of process control and statistics. In this advanced session, industry specialists will showcase the tools and methods that are needed to work more challenging problems and turn them into solutions. Speakers will cover hypothesis testing, analysis of variance (ANOVA), repeatability and reproducibility, and most importantly practical examples of using these tools in a brewery. This workshop will teach you how to effectively test problems and use data to make informed decisions.

Special Interest Session: Dry Hop Aroma in Beer—A Review

10:30–11:30 a.m. • Fiesta 3,4,6,8

Christina Schoenberger, Joh. Barth & Sohn GmbH & Co. KG

Dry hopping is a crucial part of most craft beers. This originally British technique is used today in many different ways in all emerging craft beer markets around the globe. With this technique, dry hopping has become an important research field for many brewing universities. The two main aspects that researchers want to answer are: 1) What happens during dry hopping and how can dry hopping be carried out smartly and efficiently? and 2) Are there key flavor components in hops, maybe even variety-specific ones, that can explain the unique aroma and flavor of dry hopped beers? This review gives an overview on all relevant research findings to date in this context.

Workshop: What's the Difference? Understanding and Selecting Sensory Difference Test Methods

1:30–3:30 p.m. • Flores 1–2

Meghan Peltz, Oregon State University; Lindsay Guerdrum, New Belgium Brewing Co.; Cindy-Lou Lakenburges, Anheuser-Busch, LLC

Statistics are at the core of sensory as a scientific discipline. They guide how panel leaders evoke a panel while taking bias into account, take appropriate measurements according to the desired outcome, analyze the data using appropriate statistical tools, and interpret valid data. Sensory science is applied statistics and as such, panel leaders require a wide statistical knowledge base including: running suitable tests, understanding biases, and determining outliers. In this workshop, the principles of sensory science will be applied by focusing on the most commonly used, and abused, sensory test: the difference test. Participants will walk away from this workshop knowing when to run a difference test, which one to choose, and how to utilize the panel while minimizing bias.

New and Alternate *Methods of Analysis*

3:15–3:45 p.m. • Fiesta 3,4,6,8

Karl Lakenburges, Anheuser-Busch, LLC; Mark Eurich, New Belgium Brewing Co.

Do you have a need for a new method that has not been published in the *ASBC Methods of Analysis*? Then join us for a chance to be involved in the core of what ASBC provides to its members: science that is proven, vetted, tested, peer reviewed, and endorsed by the brewing community. This session will give you the chance to make your voice heard about the technical direction of the ASBC.

Wednesday, June 17

8:30 a.m.–3:00 p.m.	Registration Desk Open	*The Studio*
8:30–10:15 a.m.	**Technical Session 9: Hop Flavor and Analytics**	*Fiesta 13–14*
	Moderator: Tom Shellhammer, Oregon State University	
	8:30 a.m. 30. M. Biendl. Hard resins: The complementary bitter fraction present in hops, pellets, and ethanol extract	
	8:55 a.m. 31. G. Hasman. Direct ESI-MS quantitation of bittering acids, isomerization, and oxidation products in hops and beer for calculation of the hop storage index and international bitterness units	
	9:20 a.m. 32. C. Schoenberger. The influence of mode of dry hopping on flavor stability of dry-hopped beers	
	9:45 a.m. 33. M. C. Qian. Key aroma compounds in "Centennial," "Citra," and "Nelson Sauvin" hop identified by aroma extract dilution analysis	
8:30–10:30 a.m.	**Special Interest Session: Science of Sour Beer**	*Fiesta 3,4,6,8*
10:40–11:40 a.m.	**Special Interest Session: "I've Always Wanted to Know..."**	*Fiesta 3,4,6,8*
1:00–2:15 p.m.	**Technical Session 10: Fermentation**	*Fiesta 13–14*
	Moderator: Jessica Davis, The Bruery	
	1:00 p.m. 34. Y. Muraoka. Very high gravity brewing: Effects of the processes on fermentation in 30°Plato wort	
	1:25 p.m. 35. A. Speers. Monitoring of industrial ale and lager brewing fermentations	
	1:50 p.m. 36. T. Irie. Analysis of sugar attenuation with a curve-fitting method and its application for industrial fermentation control	
1:00–2:15 p.m.	**Technical Session 11: Flavor and Product Stability II**	*Fiesta 3,4,6,8*
	Moderator: Lindsay Guerdrum, New Belgium Brewing Co.	
	1:00 p.m. 37. G. Zhou. Study on proanthocyanidins-rich beer	
	1:25 p.m. 38. B. M. Titus. The effects of polyphenols extracted during dry hopping on beer flavor stability	
	1:50 p.m. 39. D. J. Cook. A novel beer fining and stabilizing agent extracted from hops	
2:30–4:00 p.m.	**Closing Session with Guest Speaker: Sensory Thinking: An Essential Element to Innovation**	*Fiesta 3,4,6,8*
4:00–5:00 p.m.	**"Top Cosmos" Challenge**	*Hotel Waterfall*
5:00–11:00 p.m.	Hospitality Room Open	*Diego Rivera Room*

Wednesday Highlights

Special Interest Session: Science of Sour Beer

8:30–10:30 a.m. • Fiesta 3,4,6,8

Gwen Conley, Port Brewing Co., Lost Abbey; Kara Taylor, White Labs

Want to understand the technical elements of sour? This special interest session will focus on how to assess for consistency and quality of sour beer. Three areas for discussion include microbiology, chemistry, and sensory. As brewing scientists, how do we test for success in this intriguing and growing segment of the beer industry?

Special Interest Session: "I've Always Wanted to Know..."

10:40–11:40 a.m. • Fiesta 3,4,6,8

Christina Schoenberger, Joh. Barth & Sohn GmbH & Co. KG

Do "hop hazes" exist? What are the most important chemical markers for shelf life? How does soil impact hop growth and aroma? Do you have a burning question that needs an answer? Attendees will be encouraged to submit questions prior to the session as well as bring up questions during the session. Join us for an open forum as our experts, and everyone else, attempt to answer your questions.

Closing Session with Guest Speaker: Sensory Thinking: An Essential Element to Innovation

2:30–4:00 p.m. • Fiesta 3,4,6,8

Jennifer Jo Wiseman, E. & J. Gallo Winery

Innovation is a core value and primary growth driver for The E. & J. Gallo Winery. This has been critical to growth, particularly in the last ten years, as the winery has innovated throughout the business to deliver brands and products on a global basis that delight consumers. "Sensory thinking" is one of the essential fuels to this continuous fire of innovation. Thinking about your business in terms of the sensory experience for your consumers, shoppers, products, and processes is something that every person in the audience can practice and instill in their own company. We will explore the possibilities of reach and impact by discussing five core principles to enable innovation through sensory thinking!

ASBC Awards will be presented during this session.

"Top Cosmos" Challenge

4:00–5:00 p.m. • Hotel Waterfall

Sponsored in part by Cargill Malt.

Join us for "Top Cosmos," where teams will compete against each other in a drink-making challenge. ASBC leaders will serve as team captains to not only lead the team, but also share and discuss insights from the meeting. Teams will be judged by a panel of master "scientists" and the winning team will be titled "Top Cosmos." This is a great opportunity to be creative, exchange ideas, and celebrate the end of a successful meeting!

Get a FREE ASBC Soluble Starch Sample!

- Save time and money with ASBC's Soluble Starch—it's the only validated product of its kind available for evaluation of enzymatic activity in malt.
- ASBC's Soluble Starch is consistent and long-lasting, which in turn saves you valuable time.
- Sign up for one free 500g sample at the Registration Desk, located in The Studio.

Try a Sample Today!

Validated • Consistent • Economical

See how your lab analysis measures up!

Subscribe to the ASBC Check Sample Program

Why ASBC Check Sample?

You have the opportunity to **evaluate accuracy and precision**, **as well as instrument performance on a scheduled, regular basis**. And, you can compare your data to results from laboratories around the world!

Barley • Beer • Hops • Malt • Mycotoxins

To learn more about the program visit **asbcnet.org/publications/checksample**

Cheers to You, ASBC Corporate Members

ASBC Corporate Members contribute their knowledge, expertise, and professional involvement to ensure the continued strength of ASBC and promote excellence in the science and technology of brewing.

Alaskan Brewing Co.

Allagash Brewing Co.

American Tartaric Products, Inc.

Anchor Brewing Co.

Anheuser-Busch Inc.

Benson Polymeric Inc.

Bio-Chem Lab Inc.

Brew Hub

Briess Malting Co.

Bruker BioSpin Corp.

Cargill Malt

Cicerone Certification Program

Cloud-Sellers

Craft Brew Alliance

Dry Dock Brewing Co.

Eberbach Corp.

Ecolab

Ellutia Inc.

ERA, A Waters Company

Fremont Brewing Co.

Gusmer Enterprises

Hach

Heineken Supply Chain

Hygiena

John I Haas Inc.

Kalsec Inc.

Karbach Brewing Co.

Kirin Co., Ltd.

Logos Biosystems, Inc.

Malteurop North America Inc.

Midwest Hop and Beer Analysis LLC

MillerCoors

Molson Coors

North America Breweries

North American Craft Maltsters Guild

Novozymes North America Inc.

O'Sullivan Brothers Brewing Co.

optek-Danulat, Inc.

Pacific Western Brewing Co.

Pall Corporation

Pentair Haffmans

PQ Corporation

Profamo Inc.

Qilu University of Technology

R-Biopharm, Inc.

Rahr Malting Co.

Sapporo Breweries Ltd.

Sealed Air Corporation

Short's Brewing Co.

Siebel Institute and World Brewing Academy

Sierra Nevada Brewing Co.

Skeena Brewing Co.

Sleeman Brewing and Malting

Steinfurth, Inc.

Tallgrass Brewing Co.

The Bruery

Thermo Scientific

Thirsty Dog Brewing Co.

Union de Cervecerias Peruanas

Utah Brewers Cooperative

Weyerbacher Brewing Co.

White Labs

Wyeast Laboratories Inc.

Yakima Chief-Hopunion LLC

Zhongde Fermentation Technology Co. Ltd.

1

A contemporary tool for a new age in brewing: Bringing modern science into everyday flavor analysis

N. Garneau (1), L. GUERDRUM (2)
(1) Denver Museum of Nature and Science, Denver, CO, U.S.A.; (2) New Belgium Brewing, Fort Collins, CO, U.S.A.

Brewing sensory science has been plagued for decades with a need to standardize its flavor terminology. Despite growing support for standardization, the task has proven to be notoriously difficult, and one that unsurprisingly, due to the many challenges it poses, few have chosen to tackle. The most well-known effort toward this end was taken on by a working group composed of representatives from the American Society of Brewing Chemists (ASBC), the European Brewing Convention, and the Master Brewers Association of the Americas. Convened in the late 1970s, the group set out to create a universal system to communicate beer flavor that would be regularly assessed and updated by the ASBC. The outcome of this committee—the ASBC Flavor Wheel—was a huge step forward for the brewing industry. However, despite the call to action from the committee to the brewing industry, the wheel was not regularly updated as intended. And as of 2015, the ASBC Flavor Wheel remains in the same form as when it was first published, 36 years ago. While a model for flavor analysis remains a needed and sought-after tool, the data behind the ASBC Flavor Wheel is based on now outdated science, and in some cases is indisputably perpetuating false information. The presenters here propose a new model for beer flavor that learns from the successes of the ASBC Flavor Wheel, but is scientifically aligned with the sensory research of the last three decades, accounts for new complexities in brewing science, and is actionable by brewing professionals. The goal of this proposed beer flavor identification system is uniform use across the industry and the ability to be reevaluated regularly by the ASBC sensory sub-committee through input by brewing and sensory professionals as both language and research advance.

Lindsay Guerdrum received a B.S. degree in biochemistry and molecular biology from the University of New Mexico in Albuquerque and an M.S. degree in food science and technology from the University of California, Davis. While at UC Davis she focused on malting and brewing science under Charles Bamforth, working on gluten-free beer research. She began employment at New Belgium Brewing Company in 2011, where she is currently a sensory analyst. She has served on the ASBC Sensory Technical Subcommittee for three years as the Sensory Chair and Gluten-Measurement Subcommittee Chair.

2

Measuring the emotional response to beer: The long and the short of it!

J. HORT (1), C. Eaton (1), C. Chaya (2), K. Smart (3)
(1) University of Nottingham, Nottingham, U.K.; (2) Technical University of Madrid, Madrid, Spain; (3) SABMiller, Woking, U.K.

Beer is an emotive product and understanding consumer emotional response has been shown to give greater insights into product differentiation beyond traditional measures of liking. However the sensory tools for measuring the emotional response to beer are limited. Verbal self-report measures available commonly include a long lexicon of emotion terms which inevitably increases the potential for consumer boredom and fatigue and typically they are not beer specific. This study assessed the effectiveness of a novel approach for reducing the number of terms in a beer-specific lexicon by comparing results obtained using both a full emotion lexicon and a reduced version. The relative ability of each lexicon to discriminate between beer samples and between different consumer groups (gender and age) was evaluated. The study utilized a consumer-led lexicon generated by 3 focus groups of 5–7 subjects (n = 17) in response to 10 beer samples. Three samples were assessed at a time and subjects were asked to describe how their emotional response to any one sample was different to the other two (triadic elicitation). The focus groups generated 43 emotion terms which were subsequently used by the 17 subjects to rate their emotional response to the 14 samples. Linguistic checks and cluster analysis were used to group terms into categories of similar emotions. Nine distinct emotion categories were identified. Consumers (n = 109) rated emotional response to the 14 samples using both the full (43 items, 1 line scale for each emotion term) and reduced lexicon (9 items, 1 line scale associated with each of the 9 emotion categories). Fifty-nine consumers used the full lexicon first, whereas the remaining fifty-two used the reduced form first. Encouragingly, multiple factor analysis indicated that the emotional spaces generated by both lexicons were comparable (RV coefficient = 0.791). Nevertheless, further analyses (ANOVA and post hoc multiple comparisons) revealed noteworthy differences concerning the level of discrimination between samples. In some instances e.g. *nostalgia,* the reduced form did not highlight subtle differences captured by the use of the full lexicon. However, for some emotions e.g. *tame/safe*, grouping of emotion terms on the reduced form led to increased discriminability across beers. The different lexicons had little effect on differences in emotional response across gender, but the full lexicon did highlight more differences across age groups. Further findings of interest will be discussed in the presentation. Whilst more detailed emotion information was potentially lost through the employment of the reduced form, consumers appeared to be able to use some emotion categories to more effectively discriminate between the samples. Therefore in commercial environments, a reduced emotion lexicon may be preferable given its relative similarity to the full form for sample discriminability and its significant savings in both time and resources. However, if the aim of emotional research is to differentiate between consumer segments, particularly between age groups, then it may be preferable to use a full emotion lexicon.

Joanne Hort is the SABMiller Chair in Sensory Science and Head of the International Centre for Brewing Science (ICBS) at the University of Nottingham in the United Kingdom. Originally Joanne established the Sensory Science Centre at the university, which is internationally renowned for its sensory research and training. After developing a passion to understand the complexity of beer flavor she is now applying her expertise to progress understanding concerning multi-sensory interactions, individual variation, temporal changes in flavor perception, and the emotional response to the sensory properties of beer. Her multidisciplinary approach combining analytical, brain imaging, and sensory techniques provides rich insights into beer flavor perception. Joanne leads ICBS, which has an international reputation for its brewing research and innovative postgraduate training programs. Joanne is a member of the editorial board for JASBC, Food Quality, *and* Preference, Chemosensory Perception, and Flavour. *She is a member of ASBC and IBD and Fellow of the Institute of Food Science and Technology. She is the current chair of the European Sensory Science Society and past chair of the UK Professional Food Sensory Group.*

3

Beer quality and stability on the market

B. GADZOV (1), K. Jorge (2), R. Nixdorf (3), B. K. Maitin (4), C. Valdivieso (5), A. Guzhiev (1), T. Tian (1), J. G. Lopez (1), E. Canterranne (1)
(1) FlavorActiV Ltd., Chinnor, U.K.; (2) FlavorActiV Ltd., Rio de Janeiro, Brazil; (3) FlavorActiV Ltd., De Hague, Netherlands; (4) FlavorActiV Ltd., Bangalore, India; (5) FlavorActiV Ltd., Mexico City, Mexico

High quality beverages, plus beverage stability and batch-to-batch consistency are essential requirements for all producers. Beer flavor is not static; it is in a constant state of change requiring sensory analysis at each stage. Understanding how the beer sensory profile can be affected by various factors is critical to delivering a consistently fresh product. 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 18 different brands packaged in glass, can, and PET, taken from 36 locations from the market over a period of 24 months. In total 2,916 samples have been tasted by a professional, expert, in-house panel. The results will highlight the range and intensity of off-flavors produced in beer depending on the different packaging material (i.e. bottle, can, or PET). The findings will then be used to advise the producer on aspects of the supply chain that may be compromising quality, e.g. packaging supplier, transportation, storage, and so on. Additionally, comparing tasting results with analytical data for selected off-flavors will bring about a best practice sensory panel training criteria and methods for tasting and profiling market samples. Tasters have been trained and validated on 150 GMP flavor standards which are used globally by professional sensory panels within the beverage industry. The panel also compared analytical data available with some of the non-conformances detected in this study. The project aims to improve understanding of beer non-conformances in different types of packaging and storage conditions on the market, in addition to analyzing sensory good practices in tasting, comparing tasting with instrumental data, and monitoring and preventing faults and recalls. The study results are considered to be suitable to monitor beer stability after production.

Boris Gadzov has been FlavorActiV director of global sensory management 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 more than 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 gained a Ph.D. degree in food molecular microbiology from the University of Vienna.

4

New methods of sensory evaluation: Their implications and applications for drink-ability assessment and beer–food pairing based upon statistical and consumer studies

A. G. BARLOW (1)
(1) ALL BEER, Sheffield, U.K.

Beer flavor is increasingly important as a method for communicating brand virtues to trade customers and consumers. Master Brewer Alex Barlow designed an evaluation system (ALL BEER Flavor Notepad, ABFN) to assess beer flavor, which results in empirical results for beer balance and flavor intensity and could form a simple, useful system to communicate beer attributes for trade and consumer benefit. The integrity and usefulness of this system was put to scientific test by Nottingham University using PCA and statistical methods, the results were presented in widely acclaimed posters at WBC 2012 and EBC 2013. The objective of the most recent study is to carry out consumer trials on beer–cheese pairings and to assess whether any wider beer–food pairing rules may be determined. Cheese was selected as a suitable food for pairing due to its broad range of styles, flavors, textures, and ad hoc appreciation of beer and cheese matches. ABFN was adjusted to suit food groups and capture details of cheese production, after which some 50 cheeses were tasted to determine category differentiation for aroma, taste, and mouth-feel and to suggest suitable beer pairings, from experience. Certain of these cheeses and suggested beers were subjected to consumer testing (n = 132–134) scoring hedonic liking of beer and cheeses alone and in combination as pairings over two sessions. Within each session, three beers and cheeses were evaluated using a 9 point hedonic scale. Consumers were asked to rate the balance of the beer–cheese pairings using 5 point JAR scales. Demographics were recorded via questionnaire. Mean liking was calculated for each individual beer, cheese, and the beer–cheese pairings. Overall, hedonic scores for the cheese alone were reduced when paired with any of the beers. Clustering of consumers dependent on their demographic and common beer/cheese consumption type was performed, providing a further insight into the hedonic results. These results will be presented and discussed in the context of consumer liking of beer–cheese pairings. There is increasing interest worldwide in flavorsome and crafted beverages, notably beer. As this interest grows the place for beer at the dinner table is increasingly open; however there have been few studies into beer–food pairing or insights into techniques that can offer practical help to brewers, retailers, and consumers who are interested in this field. We believe the insights afforded by these studies offer opportunity for improved flavor evaluation and combination methodologies.

Alex Barlow was brought up in Chester in northwest England and in Zambia, Africa. His 25 years of experience in brewing and passion for beer started as a bar and cellarman in his local pub, before studying for two medical sciences degrees. He learned brewing skills at Bass' U.K. breweries, becoming the youngest qualified master brewer in 1991, before moving to police beer quality in the pubs and clubs of Yorkshire, Lincolnshire, and northeast England. He became the first Englishman to manage a Czech brewery, with Staropramen in Prague, and developed two new beer brands while gaining a taste for European beer styles. Alex is an independent brewing and flavor consultant, presenter, and sommelier. He is director of training for The Beer Academy and regularly judges international beer competitions and presents beer experience events in the United Kingdom, Europe, and North America to consumer audiences and beer retailers. Alex is the author of the ALL BEER Guide, *winner of four international awards, and has contributed to many publications. Alex provides independent beer evaluations and food pairings for www.allbeerfinder.com and continues to research beer sensory projects with the Nottingham University Brewing School.*

5

Evaluating a portable yeast pitching skid for reliable and accurate pitching for craft breweries

A. R. BHAT (1), R. Smith (2), C. Giblin (2), J. P. Carvell (1)
(1) Aber Instruments Ltd., Aberystwyth, U.K.; (2) Meantime Brewing Company, London, U.K.

Market expansion and continuous process innovation spells the need for more sophisticated yeast management systems in craft breweries. Managing yeast is of utmost importance, since consistent fermentation performance and beer quality are heavily influenced by the accuracy of pitching the exact amount of live yeast into a fermenter. Precise regulation of pitching is the key to ensuring consistent performance in terms of fermentation cycle times, extent

of yeast growth, the related efficiency of extract conversion, and the formation of yeast-derived beer flavor components. Larger commercial brewers tend to set very tight tolerances on yeast pitching rates and these need to be within ±10% of the target rate. Although most of the bigger breweries have created customized yeast dosing systems using online dielectric spectroscopy to automate their pitching, this is not always possible in the case of expanding craft breweries. There is a strong need for an affordable portable yeast dosing skid that can be connected to different yeast storage vessels/fermenters in a craft brewery, has an integrated local PLC and flow meter in its design, and can perform cone-to-cone pitching as well. In this paper, we report the performance, functioning, and benefits of a new yeast pitching skid incorporating online dielectric spectroscopy, at the Meantime Brewing Company, London, U.K. Working with different recipes, the skid was first used successfully to accurately pitch different concentrations of yeast in a fermenter, depending on the brand of beer being used. Accuracy of pitching using mass and the skid was compared. Interestingly, when mass was used to pitch yeast into the fermenter, the viable yeast concentration was overestimated, hence pitching fewer liters of yeast than necessary. This led to slower fermentations and inadequate fermentation performance. In contrast, the automatic skid estimated the right amount of live yeast, thus pitching the appropriate viable liters of yeast essential for an improved fermentation performance. The average difference in the number of liters pitched for four different brews was about 100 L or 1 hL. In addition, the °Plato (expressed as the average of four brews) was seen to decrease quicker when yeast was pitched using the skid, as compared to when it was pitched using mass. This could be due to the fact that adequate numbers of live yeast cells were pitched at the beginning of fermentation using the skid to convert the sugars in the wort into alcohol more efficiently. Improvement in fermentation performance leads to time, energy, and cost savings. Overall, the yeast pitching module helped to obtain a more uniform fermentation profile, thus making planning easier. Significant improvement in batch-to-batch consistency was also observed after its adoption.

Aditya Bhat has completed his Ph.D. and M.S. degrees in biotechnology and microbiology from reputed universities in the United Kingdom. Having performed his M.S. dissertation project on the Aber Biomass Monitor, he is presently working as a product applications manager for Aber Instruments Ltd, Aberystwyth, U.K. With rich academic and industrial experience behind him, he takes special interest in measurement of cell concentration in various brewing and biopharmaceutical processes.

6

Practical experiences with an automated yeast cell counter using methylene blue in breweries

K. M. THOMSON (1), J. P. Carvell (1), A. R. Bhat (1)
(1) Aber Instruments Ltd., Aberystwyth, U.K.

Automation in breweries has always been sought after, especially with respect to cell counting procedures that reduce errors associated with manual counting and inter-operator variability. Along with being expensive, the fluorescent dyes used in most automated cell counters pose greater hazards and health and safety concerns. In addition, viability estimation using fluorescent dyes tends to be a two step process, or require dual staining, as opposed to a simple one-step process with classical stains such as methylene blue and methylene violet. Therefore, "the gold standard" methylene blue dye exclusion method is still favored in the industry. In this paper, we report the performance, functioning, and benefits of an automated cell counter (the Aber Countstar, Aber Instruments, U.K.) that analyzes yeast viability using the methylene blue dye exclusion method for brewer's yeast. Previous work had demonstrated the instrument's accuracy and improved consistency with baker's yeast when compared to manual counts. In this study, the Countstar was tested across a selection of industrial dried lager and ale yeasts. In addition, bottled wheat beer samples containing trub, that can pose a challenging background, were tested using the Countstar. Inter-operator variability was assessed using automated and manual methods, where cell concentrations and viabilities were recorded by four different operators using both procedures and compared for consistency. All results from the Countstar were compared to manual cell counts using the hemacytometer. Variables were kept to a minimum using the two techniques, since both methods use bright-field microscopy and methylene blue. The study also includes extensive tests performed by The Boston Beer Company (USA), where yeast from different processes in the brewery, namely fermentation, propagation, and yeast storage was analyzed and compared using the automated and manual methods. The Countstar readings matched well with hemacytometer counts for various active dry yeasts (e.g. R^2 = 0.991), through a range of concentrations with readings. However, some active dry strains did not correlate well, as with one ale yeast tested (R^2 = 0.537), although this was due to high variation in the manual cell counts (R^2 = 0.993 Countstar; 0.292 manual). A simple evaluation of some parameters in the Countstar software improved accuracy of measuring the wheat beer samples with interfering trub particles in association with manual assessments (R^2 = 0.938). The automated Countstar reduced inter-operator errors among four operators considerably, a major hindrance with manual analyses. The tests performed at The Boston Beer Company demonstrated that the automated counter can be used successfully with both lager and ale yeast, throughout various stages of the brewing process and highlighted the instrument's ease of use and consistency across the brewery.

Katy Thomson is a research scientist and product specialist for Aber Instruments Ltd., a company based in Aberystwyth, U.K. Katy has a B.S. (honors) in biology, from the University of Manchester and a master's degree from Queen Mary University of London. She has keen interests in microbiology and animal and cellular physiology. Prior to joining Aber Instruments, Katy worked as a sustainability consultant, taking client relating and project management skills forward. During her time at Aber Instruments, she has helped develop the Countstar, an automated cell counter to a higher standard through designing and implementing various experiments to test the instrument and software. Through this process, she quickly became the product specialist for the Aber Countstar within the company and is now heavily involved in customer support. She has also published papers on these findings, including an article for Brauwelt International *and the* Journal of the Institute of Brewing.

7

Rapid yeast viability detection method in complex brewing samples using the Cellometer X2 image cytometry

L. L. CHAN (1), T. Smith (1), D. Kuksin (1), K. McCulley (1)
(1) Nexcelom Bioscience, Lawrence, MA, U.S.A.

One of the major parameters measured in beer fermentation is the viability of yeast in the sample. Yeast viability can be monitored throughout fermentation to optimize brewing performance that may increase yield as well as produce consistent quality products. Recently, a novel imaging cytometry method has been demonstrated to rapidly and accurately measure yeast viability via fluorescent staining. The simplest fluorescent viability staining method utilizes propidium iodide (PI) to identify the dead yeast cells in the sample. By counting the total yeast cells in bright-field image and dead cells in PI fluorescence, one can accurately determine viability. However, single fluorescence may not be

adequate for yeast in specialty beer where complex materials are added into the fermentation creating numerous background debris. The debris can cause inaccurate over-counting of total yeast cells, which can artificially generate higher viability. In this work, we developed a novel dual-fluorescence viability method using an acridine orange (AO) and PI nuclear staining technique. One of the most complicated samples is yeast with corn mash material, and by testing AO/PI with this sample, it can validate the capability of this staining method. Numerous fluorescent stains were examined before selecting AO and PI. In addition, a special buffer was used in order to increase the fluorescence signals generated by AO/PI. In order to validate the method, SYTO 9, CFDA, calcein AM, Calcofluor, AO, PI, ethidium bromide, and DAPI were tested with yeast in corn mash samples. Furthermore, the yeast viability was measured for a fermentation from 2 to 55 hours, and the results were compared to the manual counting methylene blue method. This viability method can be used with a variety of yeast samples that can produce accurate results for optimizing brewing 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. 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).

8

Contributions from the β-glucosidase activity of brewing yeast to hoppy beer aroma

D. C. SHARP (1), T. H. Shellhammer (1)
(1) Oregon State University, Corvallis, OR, U.S.A.

Non-volatile hop-derived aroma precursors contribute to aroma in finished beer. Specifically, glycosidically bound terpenoids extracted from hops during the brewing process are hydrolyzed to release volatile aglycones. Previous studies show that the complexity of hop aroma can be partly attributed to these water-soluble glycosides through yeast biotransformations. However, the effect of yeast strain on biotransformation has not been fully investigated. This study quantifies the hydrolytic activity of different yeast strains on glycosidically bound terpenoids and determines whether differences in these activities change hop aroma profiles in beer. β-Glucosidase activities for 80 different yeast strains were quantified as a measure of the glycoside hydrolysis capability of each yeast. 4-Methylumbelliferyl β-D-glucopyranoside (4-MUG) was used as a substrate and the fluorescence emission of the liberated aglycone, 4-methylumbelliferone, was measured and normalized by optical density. Bench-top fermentations were conducted with a subset of the initial population using yeasts exhibiting a range of glucosidase activities. After fermentation was complete, terpenoid contents in each beer were measured by solid phase micro extraction with GC-MS analysis. Yeasts were found to have a range of β-glucosidase activities from 0 U/L to ~250 U/L with an average of 95 U/L (1 U catalyzes the hydrolysis of 1 µmol substrate per min at pH 5). Increases in terpenoid levels as a result of yeast biotransformation were observed. For example, compared to unfermented wort, linalool contents increased between 45% and 78% depending on yeast strain. These results help explain the extent to which different brewing yeasts are able to contribute to hoppy beer aroma through the biotransformation of hop-derived compounds. In a broader sense, the results from this project will aid brewers in selecting yeast strains during recipe development and to better understand the contributions of yeast to hop-derived aroma in beer.

Daniel Sharp is a Ph.D. candidate in the Food Science and Technology Department at Oregon State University, focusing on hop studies being conducted in Thomas Shellhammer's lab. He earned a B.A. degree from the University of Oregon and his master's degree from Oregon State University. Daniel is the 2012–2014 recipient of the InBev Baillett-Latour Brewing Scholarship for his Ph.D. work toward identifying contributing factors of hop aroma in finished beer. He also enjoys backcountry skiing when the snow is good and time allows.

9

Sesquiterpene oxidation products as key impact compounds for "kettle hop" aroma

T. PRAET (1), F. Van Opstaele (1), G. Aerts (1), L. De Cooman (1)
(1) KU Leuven, Ghent, Belgium

Although the "dry hopping" process is gaining popularity, lager beers with a refined "kettle hop aroma," imparted by (early) addition of hops to the boiling kettle, are still widely consumed. This highly desired spicy/herbal top note has been correlated to sesquiterpene oxidation products (SOPs), formed during ageing of hops. SOPs are also presumed to arise during kettle boiling by oxidation of sesquiterpene hydrocarbons (SHCs). However, whether SOPs are actually formed upon boiling, and how exactly they contribute to "kettle hop aroma," is, despite the efforts of many scientists, still relatively unclear. Therefore, we aimed at obtaining scientific solid insights into formation and flavor-activity of these SOPs upon lab-scale boiling, and at investigation of the validity of these findings in real brewing practice. Hop essential oils (cv. Saaz, Hallertau Tradition, Perle, Magnum) and SHC fractions (isolated via solid phase extraction [SPE], cv. Saaz) were boiled (lab scale) in both aqueous and wort media and samples were analyzed via HS-SPME-GC-MS for comprehensive characterization of volatile hop-derived profiles. For sensory evaluation, GC-olfactometry and descriptive analysis (trained panel) were combined. The SOP fingerprint of commercial kettle-hopped American beers was recorded and flavor-active constituents were determined (GC-O). Specific hopped (cv. Saaz) lager beers were prepared at our pilot plant (4 hL) and samples were screened for SOPs to map their formation and behavior along the brewing process. We statistically demonstrated a discrimination between unboiled and boiled hop oil and established a general increase in the level of SOPs upon boiling, which is attributed to both quantitative (i.e. increased levels, typical α-humulene and β-caryophyllene derivatives) and qualitative (i.e. newly formed compounds) changes in the hop-derived volatile profile. Interestingly, SOP formation is clearly positively correlated with the initial boiled hop oil concentration (e.g. 10 g/L hop essential oil cv. Saaz: SOPs recovery up to 258% ± 23 [n = 3]) and independent of the investigated hop variety. SPE isolation of SOPs after boiling of a SHC fraction unambiguously proved oxidation of SHCs. Via GC-O, humulene epoxide III, humulenol II, caryophylla-4(12),8(13) diene-5α/β-ol, 3Z-caryophylla-3,8(13)-diene-5α/β-ol, and 14-hydroxy-β-caryohyllene were detected in flavor-active zones and non-aromatized iso-α-bittered lager beers, spiked with the SOP fraction, were described as "hoppy" and "spicy." Remarkably, the newly formed compounds and constituents, characterized by increased levels, were also detected in commercial kettle-hopped American beers and the same α-humulene and β-caryophyllene oxidation products were found to be flavor-active in these beers upon GC-O analyses. In addition, pilot brews indicate that "early" kettle hopping does not lead to losses of all hop oil compounds, as believed by many brewers, but instead introduces SOPs to wort. In conclusion, the flavor-active SOPs are candidate key character impact compounds for "kettle hop aroma." Insights into development of "kettle hop aroma" is of importance for both hop

scientists and brewers and should lead to more deliberate hop additions with respect to the desired beer flavor.

Tatiana Praet (born 1987) is a Ph.D. student at the Catholic University of Leuven (KU Leuven, Belgium). In 2011, she received a master's degree in industrial engineering (biochemistry) at KAHO Sint-Lieven. Currently, she is performing research in the area of brewing technology at the Laboratory of Enzyme, Fermentation and Brewing Technology, focusing on aroma-active hop-derived volatiles that contribute to beer flavor. Tatiana acquired an IWT-grant from the Flemish Government (2011) and the Barth-Haas Grant (2012) and received the MBAA Presidential Award (2014).

10

The influence of oil content on aroma in beer dry-hopped with Cascade

D. M. VOLLMER (1), Y. P. Qian (1), G. Shellhammer (2), T. H. Shellhammer (1)
(1) Oregon State University, Corvallis, OR, U.S.A.; (2) Shellhammer Consulting LLC, Corvallis, OR, U.S.A.

Dry-hopping is a method whereby hops are added post-fermentation to deliver hop aroma to beer without subjecting the hop material to the volatilization that occurs in hot-side hopping techniques. The oil fraction of hop material is a reservoir of compounds with aromatic properties and we hypothesized that dry-hopping with hops having greater oil content would lead to beer with more aroma. Whole-cone Cascade hops with three different levels of total oil (0.6 mL/100 g; 1.2 mL/100 g; 2.0 mL/100 g) were used to separately dry-hop 12 L of pale ale at a fixed dry-hopping rate of 3.8 g/L for 12 and 24 hours. Dry-hopped beers were evaluated using descriptive analysis techniques and analyzed instrumentally by SBSE GC-MS. Sensory differences among the beers prepared with different levels of oil were shown to not be influenced by exposure time ($P = 0.718$) and were suggestively influenced by the level of total oil content ($P = 0.055$). Instrumentally, the effect of time was also deemed not significant for all of the target analytes with the exception of linalool and geraniol, and to some extent nerol and β-eudesmol. For the effect of oil, significant differences were measured among the treatments in terms of the concentrations of linalool, geraniol, geranyl acetate, and caryophyllene oxide among others. The conclusions of this work suggest that longer dry-hopping times do not necessarily result in increased aroma intensity in dry-hopped beers from a sensory perspective. There is a slight trend in hop aroma intensity with increasing hop oil content but this needs further testing to verify. Instrumentally, dry-hopping for extended periods of time, or with hops that have higher levels of total oil, resulted in increased levels of certain analytes, particularly terpene alcohols. This work provides insight into the role of hop oil content and quality and could elucidate which raw material properties serve as indicators of beer performance for hops primarily used for aroma purposes.

Daniel Vollmer is a doctoral candidate in the Food and Fermentation Science program at Oregon State University working in Thomas Shellhammer's lab. His research examines the origins of hop aroma in beer, specifically studying the aroma of oxidized hops, water-soluble flavor precursors in hops, and the influence of hop oil content on dry-hop aroma in beer. Additionally he has developed course work in support of OSU's annual Beer Analyses workshop series, focusing on quality assurance and control, and contributes to the execution and delivery of these courses. Daniel is a member of the American Society of Brewing Chemists and the Institute of Food Technologists. He completed the UC Davis Master Brewers Program in 2012 and received his M.S. and B.S. degrees in food science from the University of Massachusetts, Amherst, in 2011 and 2010, respectively.

11

Measurement of terpene alcohols and their stereoisomers in beer and the applications for improving beer hop aroma

J. WEI (1), W. D. Liang (1), W. Lu (2), L. Xiang (3)
(1) China National Research Institute of Food & Fermentation Industries, Beijing, China; (2) Xinjiang University, Urmuqi, China; (3) Tianjin University of Science and Technology, Tianjin, China

Hop aroma was considered as the soul of beer and 12 hop aroma compounds, including terpene alcohols and stereoisomers, in beer and hops were measured simultaneously and investigated using a quick, simple, and economical method based on GC-MS with only one single chiral column. As far as the major terpene alcohols and their stereoisomers are concerned, different sensory thresholds in beer were established between stereoisomers by ASTM679 method. For example, the threshold of R- and S-linalool, R- and S-β-citronellol in beer were 2.60 μg/L, 180 μg/L, 23.78 μg/L, and 7.00 μg/L, respectively. Different biotransformation was also studied for terpineols of hops during fermentation. R-(−)-linalool predominantly in hop was reduced into S-(+)-linalool, (+) and (−) of α-terpineol. Geraniol in hop was reduced into R-(+)-β-citronellol, geranyl acetate, R- and S-linalool et al. Generally, the loss of hop aroma during brewing contributes to evaporation loss during boiling and biotransformation of terpenoids in hop with low sensory threshold into stereoisomers or other terpenoids with high thresholds. In this study, the main hop aroma compounds in different beers, including R-(−)-linalool, geraniol, and R-(+)-β-citronellol, were detected with the ranges of 1.52~144.94 μg/L, 1.18~253.8 μg/L, and 0.64~103.17 μg/L, respectively. At the same time, the utilization rate of R-(−)-linalool was investigated with different adding points as follows: dry-hopping (36%) > whirlpool-hopping (31%) > hopping after boiling (25%) > 10 min of hopping before the end of boiling (5%). The higher concentration of R-(−)-linalool was detected, while the later the aroma hop was added. In addition, different hops have different concentration and utilization rates for R-(−)-linalool, which should also be considered when breweries select aroma hops varieties. Meanwhile, sensory evaluation of hop aroma in the final beer also can't be ignored.

Jiang Wei is a senior engineer and holds a Ph.D. degree. In 2008 she became a member of the China National Research Institute of Food and Fermentation Industries. She is involved in flavor analysis of alcoholic beverages and raw materials using GC-MS and GC-O-MS, studying brewing technology of specialty beers. Meanwhile, she has performed research on wine authenticity and regional origin with NMR and IRMS. In 2014, she was awarded the first-place prize from the SinoLight Corporation for Science and Technology Progress and the third-place prize from the China Alcoholic Drinks Association for Science and Technology Progress. In 2011, she was named the outstanding employee of the China National Research Institute of Food and Fermentation Industries.

12

Non-volatile metabolites associated with flavor stability in beer

A. L. HEUBERGER (1), D. Sedin (2), P. Bouckaert (2), L. Guerdrum (2), K. Kirkpatrick (2), C. D. Broeckling (1), J. E. Prenni (1)
(1) Colorado State University, Fort Collins, CO, U.S.A.; (2) New Belgium Brewing, Fort Collins, CO, U.S.A.

Flavor stability is vital to the brewing industry as products are often stored for long durations. The use of an accelerated model that evaluates new brewing techniques to improve flavor stability is invaluable. We tested a model that stores bottled beer at high temperatures to estimate flavor stability after long-term cold storage. Additionally, three brewing methods were compared that are predicted to improve flavor stability: use of antioxidant crowns,

removal of pro-oxidants, and varying hops. Two beers, an amber ale (AA) and India pale ale (IPA) were brewed using modified methods with the goal of improving flavor stability during storage. Control and test beers were stored for 2 months at cold temperatures and also at 37°C for 1–7 days. Non-targeted metabolomics was conducted by injecting 1 μL of beer into a Waters Acquity UPLC (1.0 × 100 mm C8 column, water-acetonitrile gradient) coupled to a Waters Xevo G2 ESI-TOF-MS (positive ionization) operating in MSE mode. Data analysis was performed using XCMS, RamClust (a custom feature clustering algorithm), and the NIST-MS search program for compound annotation. Sensory analysis revealed no significant difference in flavor, aroma, or appearance for the AA beer after 2 months of cold storage; however the test IPAs resulted in superior aging (i.e. more stable) profiles within the first 2 months. The UPLC-MS metabolite profiling revealed metabolites that varied among the IPA methods, but not the modified AA beer, and included purines, amino acids, iso-α-acids, and alkaloids. The high temperature incubation revealed metabolites that differed between the control and test beers over the 7-day time course, including several purines previously shown to change during beer storage. Taken together, these data support that variation in purine compounds can be interpreted as a marker of beer aging. Thus, the association between purines and aging could be used to screen experimental methods for improved beer stability in conjunction with accelerated aging at high temperature.

Adam Heuberger is an assistant professor in the Department of Horticulture and Landscape Architecture at Colorado State University. He received his B.S. degree in molecular biology from the University of Wisconsin-Madison in 2004. In 2008, Adam received an M.S. degree in plant genetics at UW-Madison, where he studied molecular components of plant defense responses to pathogens. Adam received a Ph.D. degree in plant genetics from Colorado State University in 2011, where he characterized the influence of genetic diversity and growing environment on the rice metabolome. Adam joined the Colorado State University Proteomics and Metabolomics Facility in 2011 as a GC-MS specialist and as faculty in the Department of Horticulture in 2014. His laboratory studies biochemical and phytonutrient diversity in food crops and plant metabolites associated with sensory quality in foods. This research integrates techniques in the fields of metabolomics, analytical chemistry, food science, and plant genomics.

13

What compound is primarily responsible for the metallic flavor in beer?

N. DOI (1), M. Kobayashi (1), S. Masuda (1), M. Aizawa (1)
(1) Asahi Breweries, Ltd., Ibaraki, Japan

The perceived quality of beer is heavily based on its flavor; therefore, flavor is one of beer's most important components. Among the most important flavors associated with beer, a metallic taste, even if present in trace amounts, imparts a certain unpleasantness to the consumer. Although a number of compounds have been reported to contribute to a metallic flavor in beer and other alcoholic beverages such as wine, none have been identified as the primary cause. In this study, to identify which compound is primarily responsible for the metallic flavor in beer, we investigated the concentrations and odor thresholds of several compounds previously reported as contributors. Using gas chromatography–olfactometry and gas chromatography–mass spectrometry, we identified the following three compounds as the main imparters of a metallic flavor: 1-octen-3-one (OEO); 1,5-octadien-3-one (ODO); and 4,5-epoxy-2-decenal (epoxy). The reason that none of these compounds have previously been identified as the primary cause of a metallic flavor is that their concentration and odor thresholds in beer are too low. Our analysis revealed that the concentrations of ODO and epoxy in fresh beer were lower than their odor thresholds; conversely, the concentration of OEO was higher than its odor threshold. These results suggest that in fresh beer, OEO is the compound primarily responsible for the metallic flavor and that the other compounds we identified as contributors do not impart a metallic flavor to fresh beer independently. Further analysis also revealed that the concentration of epoxy increased during beer storage. The concentration of epoxy in aged beer was higher than its odor thresholds. This result suggests that epoxy is also responsible for the metallic flavor in aged beer.

Norio Doi has been a researcher in the Research & Development Laboratories for Alcohol Beverages at Asahi Breweries, Ltd. since 2009. In 2009, he received his M.Eng. degree in polymer chemistry from Kyoto University, where he focused on tissue engineering.

14

Permeation of volatile organic compounds into packaged beer—Tools for practice oriented simulation and analysis

N. RETTBERG (1)
(1) VLB Berlin, Berlin, Germany

Distribution of packaged beer from brewery to point of sale is a critical process, especially when beer is subject to long-distance transport such as overseas shipping. Heat, light, humidity, and movement are factors that may alter the integrity of packaging materials as well as beer quality. In addition, packaged beer may be exposed to an environment polluted by volatile organic compounds (VOCs). VOCs may be released by microbial attack on wooden pallets, as vapors from cardboard boxes, but can also be emitted from other cargo or machinery of the transport vehicle. In order to ensure product quality and safety packaging materials such as crown cork (liners), PET bottles, and closures are frequently evaluated for their barrier properties concerning O_2 uptake or CO_2 loss. A permeation test for VOCs is rare, and even trace concentrations of some compounds (e.g. chlorophenols such as 2,4,6-trichloroanisole) are known to have negative impact on the organoleptic properties of foods. This paper presents the experimental setup for practice oriented permeation testing of packaging materials for VOCs. Permeation testing includes an experimental setup to simulate long-distance transports under defined and controlled VOC atmosphere, as well as sophisticated analytical tools for identification and quantification of possible contaminants. Depending on the VOCs employed in permeation testing GC-NCI-MS and GC-MS/MS combined with stable isotope dilution assays ensure the highest accuracy of the analytical data. In addition to a detailed description of permeation testing and analysis, the paper includes analytical data recorded for different packaging materials under varying experimental conditions. The data will sensitize brewers to reassess their packaging testing procedures, especially if beer is designated for export trade.

Nils Rettberg (born 1983) is trained as a brewer and maltster, holding a diploma in biotechnology with a focus on brewing science from TU Berlin. Initiated by his diploma thesis on "Flavour Active Epoxydecenals from Lipid Oxidation," he developed a deep interest in the analysis of those 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" under the supervision of Prof. Leif-A. Garbe. Simultaneously, he was a research associate at TU Berlin (Chair of Bioanalytics) and VLB (Research Institute for Special Analyses), where he was involved in several research projects and teaching. In January 2015 Nils became head of the Research Institute for Special Analysis at VLB Berlin.

15

Improvement of wort foam stability by yeast-derived substances

Y. KATAYAMA (1), T. Iimure (1), T. Kurihara (1), Y. Kozaki (1), S. Tamura (1), T. Nakamura (1)
(1) Sapporo Breweries Ltd., Yaizu, Japan

Foam is one of the most important properties of non-alcoholic/alcoholic beer. We worked on improvement of wort foam stability to improve the foam quality of non-alcoholic beer containing malt and hops. As a result, the foam stability of the wort was dramatically improved by adding substances released from the yeast. Foam quality is affected by many factors such as raw materials, process conditions, and yeast. Yeast plays both positive and negative roles in foaming. It releases foam-negative substances such as lipids, ethanol, and proteases. Conversely, yeast-derived compounds such as mannoprotein are involved in foam formation and stabilization. In this study, yeast cultivated without malt and hops was suspended in distilled water. The suspension was centrifuged and the supernatant was freeze-dried. The dried extracts were then mixed with the hopped wort (10 mg/L). The wort with or without yeast-derived substances was carbonated. Foam stability was measured using the NIBEM test. The NIBEM values for the wort increased by more than 150 sec when yeast-derived substances were added. There was no effect when yeast extracts were added to the final beer, presumably because yeast-derived substances in the beer were sufficient. In Japan, 0.00% non-alcoholic beer is popular with consumers. However, it is not always easy to develop alcohol-free beverages using yeast. Our studies indicate that yeast extracts improve wort foam stability without adding viable yeast into the wort. Therefore, it will be easier to accomplish both alcohol-free and improvement of foam stability in non-alcoholic beer. We are now investigating the mechanism of the wort foam stabilized by using yeast. The understanding of the mechanism may contribute to the elucidation of foam formation during beer fermentation as well as development of non-alcoholic beer.

Yuta Katayama received his M.S. degree in agricultural chemistry from Tohoku University in 2007 and joined the Product and Technology Development Center of Sapporo Breweries Ltd. From 2007 to 2009, he mainly evaluated malts and hops using the pilot brewing plants. Since 2009, he has worked in the Frontier Laboratories of Value Creation and studies the gushing phenomenon, foam stability, and so on.

16

Influence of hop products and natural foam enhancer on beer foam

C. NEUGRODDA (1), M. Gastl (1), T. Becker (1)
(1) TUM – Lehrstuhl für Brau- und Getränketechnologie, Freising, Germany

Besides turbidity, beer foam is one of the most important quality parameters of beer. The consumer expects a stable, homogeneous, and fine-pored foam. For brewers, there exists only limited possibilities that allow them to enhance the beer foam stability. The German Purity Law allows, for example, the option of increasing the hop dosage and thereby improving the beer foam. However, this also has an effect on bitterness and impacts the final sensory profile of the beer. The brewer may also choose different hop products; however there are no conclusive studies illustrating how conventional hop products (pellets type 90, ethanol extract, and CO_2 extract) affect the foam stability of beer. Brewers who do not brew according to the German Purity Law may use foam enhancing products such as propylene glycol alginate, iso extract, and tetrahydro-iso extract. The positive influence of these products on foam stability has previously been published. With a growing trend toward natural products, the consumer increasingly looks favorably on natural ingredients. Therefore we used natural foam enhancers such as an α-acid extract and a yeast product for our research. Like other studies we used three foam analysis methods and a method to quantitatively calculate the percentage of foam cling adherence. In contrast to other studies, which evaluated foam stability, but neglected the sensory part, we did a sensory evaluation of the produced beers. All experimental beers were evaluated according to the DLG approved scheme. The bitterness of the hoppy beers produced was characterized in more detail by assessing them according to the Kaltner scheme. Additionally, reference photos of different beer foams were used to visually assess the foam of the brewed experimental beers. Our results showed that hop products, even conventional hop products, and other foam enhancers have different impacts on foam stability. Additionally we created a foam value (which included all foam methods) because foam analysis reacted differently to the used product. This means there is an increase in one foam measurement, but if measured with another stability test this increment is not detected. The sensory assessment revealed that some products had a negative effect on the sensory profile of the beer. In addition the foam texture of some products was very unnatural. It must also be mentioned that some hop products were difficult to handle.

Christoph Neugrodda was born in Trier, Germany. After completing his military service in 2003, he began an apprenticeship as a brewer and maltster at the Bitburger brewery in Bitburg, Germany, finishing in 2006 as the best of the examination. Until beginning his studies, he worked as a brewer at the Bitburger brewery. In 2006, he started studying brewing and beverage technology at the Technische Universität München-Weihenstephan, Germany. He graduated as an engineer with a Dipl.-Ing. degree in 2012 and completed his diploma thesis on hop proteins. Since 2012 he has been working as a Ph.D. fellow at the Institute for Brewing and Beverage Technology in Weihenstephan. His research focus is the influence of texture and molecular composition of the foam on the flavor release from beer.

17

The influence of beer protein components and content on beer colloidal and foam quality

Y. ZHOU (1), Z. Lin (1), Y. Wang (1), H. Sun (1), S. Chen (1)
(1) Technical Centre, Beijing Yanjing Brewery Group Co. Ltd., Beijing, China

In this study, protein analyzer and high performance gel filtration chromatography (HPGFC) were applied for qualitative and quantitative analysis of protein components in beer to investigate the influence of protein components on colloidal stability and foam stability and identify haze-active and foam-positive components. Comparing the changes in protein distribution and content in beer samples after a forcing test, total nitrogen in beer decreased and the content of protein under 25 kDa molecular weight (MW) was obviously reduced, while the proteins with an apparent MW >45 kDa were increased. The results demonstrated that proteins with an MW <25 kDa in beer were prone to oxidation and polymerization or interaction with other substances, forming macromolecular substances or insoluble haze particles in beer. Stepwise regression analysis showed proteins with an MW of 9.5 kDa and 0.9 kDa had a positive correlation with a sensitive protein. The higher the content of protein at 9.5 kDa in beer, the higher the EBC turbidity value. It suggested that when the 9.5 kDa protein exceeds 90 mg/L the shelf life of a beer would be affected. The content of protein components with an MW >5 kDa decreased significantly at around 30% in the foam-removed sample compared with the original beer. It revealed that beer foam contains high levels of proteins with an MW >5

kDa. It was worth noticing that the lower the content of MW 5–25 kDa proteins, the worse the beer foam performance. Therefore, beer foam-positive proteins mainly were distributed in the range of 5–25 kDa. The correlation of protein components and other physical-chemical parameters with beer head retention was analyzed. It indicated that the 43 kDa and 9.5 kDa proteins had a positive correlation with foam retention, while pH in the range of 4.0–4.6 had a negative influence. CO_2 content had a significantly positive effect, while the impact of total polyphenols was not obvious. More beer samples (100) were determined for investigating the influence of protein components and iso-α-acid on foam retention using partial least squares regression (PLSR). Results suggested that protein components with an MW of 43 kDa, 9.5 kDa, and 2 kDa and iso-α-acid had more impact on foam retention, of which the 9.5 kDa protein was an important foam-positive protein and the advised level is 80–90 mg/L. Further study on protein components in wort after boiling was also carried out. Protein contents in Congress wort prepared by eight varieties of malts and in the wort after boiling for 30 min were measured. The results illustrated the >45 kDa proteins in wort decreased significantly after boiling. Metcalfe, Baudin, and Gan Pi #4 had relatively higher foam-positive protein contents in Congress wort, while Gan Pi #4, Metcalfe, and Scarlett had relatively higher foam-positive protein content in boiled wort. It is interesting that Metcalfe showed the least protein content variation after boiling, while Gairdner presented the largest variation.

Zhou Yunyun was born in 1987. She graduated with a master's degree in bioengineering from Jiangnan University in 2013. Since 2013 she has been employed in the Technical Centre, Beijing Yanjing Brewery Group Co. Ltd., Beijing, China.

18

Fermentation ability of bottom fermenting yeast exhibiting defective entry into the quiescent state

M. Oomuro (1), T. KATO (1), H. Yamagishi (1), K. Suzuki (1), M. Aizawa (1), Y. Zhou (2), D. Watanabe (3), T. Akao (2), N. Goto (2)
(1) Asahi Breweries Ltd., Moriya-shi, Japan; (2) National Research Institute of Brewing, Higashihiroshima-shi, Japan; (3) Nara Institute of Science and Technology, Ikoma-shi, Japan

In beer brewing, the yeast plays an important role not only in the alcohol production but also in the flavor profiles of beer. Therefore, the fermentation ability of brewing yeast affects the quality of beer products. The fermentation ability of brewer's yeast has been studied for a long time. Recently, it was reported that the elevated fermentation ability of *Saccharomyces cerevisiae* yeast used for Japanese sake brewing is related to the defective transition into the G0 phase (quiescent state) in the cell cycle. To investigate the relationship between the G0 entry and the fermentation ability of bottom-fermenting yeast, we constructed two genetically modified strains of Weihenstephan34/70. One is a *S. cerevisiae* type *RIM15* gene-disrupted strain, the other is a *S. cerevisiae* type *CLN3-1* mutant strain. Both strains exhibited the phenotypic properties characterized by the defective entry into the quiescent state. As a result of the fermentation test in the synthetic medium, it was revealed that the fermentation abilities of the constructed strains, such as sugar utilization efficiency, were enhanced compared to those of the wild-type strains. These results suggest that there is a relationship between the fermentation ability and cell cycle in bottom-fermenting yeast and that the manipulation of the relevant genes leads to the construction of yeast strains with higher fermentation ability. This is the first report that indicates the defective G0 entry may induce the modified fermentation profiles of bottom-fermenting yeast.

Taku Kato earned a Ph.D. degree in brewing microbiology in 2009 from the Department of Molecular Biotechnology, Graduate School of Advanced Sciences of Matter, Hiroshima University. In 2009 Taku joined the Production Department in the Shikoku brewery of Asahi Breweries Ltd and since 2010 has worked in the Department of Brewing Microbiology, Research & Development Laboratories for Brewing of Asahi Breweries Ltd.

19

Search for genetic markers for lactic acid bacteria beer-spoilage and the role of dissolved CO_2/pressure on bacterial growth in beer

J. BERGSVEINSON (1), B. Ziola (1)
(1) University of Saskatchewan, Saskatoon, SK, Canada

The search for a small set of universal genetic markers for beer-spoilage by lactic acid bacteria (LAB) has long been of interest for researchers and brewers alike. To date, only a few genes have been proposed to confer the ability to spoil beer and all are purported to solely mediate the stress of hops. Unfortunately, these hop-tolerance genes are not the "Holy Grail" of genetic indicators, as they are not foolproof markers of beer-spoilage. Specifically, these genes are not found in all LAB that cause spoilage and, conversely, are sometimes found in LAB with limited beer-spoilage ability. Thus much remains to be investigated regarding the genetics and physiology of LAB beer-spoilage isolates in relation to other physiological stresses present in beer, such as dissolved CO_2/pressure. The impetus to expand the focus of investigation of these isolates is increased in light of the recent appreciation of the role some LAB isolates play in fermenting lambic beers and selected specialty craft brews. Under certain circumstances, flavor compounds produced by LAB contribute favorably to the flavor profile of a beer, though when these compounds are over produced or are "undesired," they spoil the beer. This suggests that there is either a relative scale of brewing-related virulence for LAB isolates (i.e., the extent to which an isolate can grow and metabolize in beer) or that differences in the physiochemical properties of a given beer limits which LAB isolates can grow in it. This poses an interesting dilemma as to how best to define brewing-related LAB and how to detect virulent, spoilage-LAB versus their non-spoilage counterparts. To investigate differences in LAB genetics and the resulting physiology of isolates with different beer-growth capabilities, we have sequenced the genomes of six LAB isolates via the Illumina MiSeq platform and performed subsequent comparative genomics and detailed plasmid profile analysis. We also assessed the transcriptional activity of three of these isolates via RNA sequencing with the Illumina HiSeq platform under conditions of varying hop concentrations, as well as dissolved CO_2 levels, in beer. Further, we assessed alterations in the fatty acid profile of 10 LAB isolates of interest under conditions of varying dissolved CO_2 levels in beer via gas chromatography. Analysis of these data sets indicates that the search for beer-spoilage indicator genes must be expanded beyond hop-tolerance genes to include conserved regulatory elements such as non-coding RNAs and DNAs, and that strong beer-spoilage potential is indicated by selected genetic pathways. Additionally, the data reveal the importance of fatty acid adaptations in correlation with dissolved CO_2/pressure, as this is clearly a selective pressure for the virulence of LAB in beer. In sum, the expectation of finding a small subset of "universal" or "Holy Grail" genes in relation to beer-spoilage must be curtailed. Instead, expression of genes from multiple physiological systems needs to be further analyzed vis-à-vis relevance to LAB growth in and spoilage of beer.

Jordyn Bergsveinson graduated from the University of Saskatchewan in 2010 with a B.S. (honors) degree in microbiology and immunology. She then began a master's program under the supervision of Barry Ziola in the area of brewing microbiology

at the University of Saskatchewan and converted from an M.S. program to a Ph.D. program in December 2011 and is looking to finish her Ph.D. degree in August 2015. Her Ph.D. work is focused on the detailed genetic and physiological mechanisms of lactic acid bacteria for the purpose of correctly identifying true beer-spoiling organisms.

20

Gushing Task Force: Round table on "primary gushing"

C. SCHOENBERGER (1), G. Derdelinckx (2), M. Gastl (3), J. Titze (4)
(1) J. Barth & Son, Nuremberg, Germany; (2) KULeuven-FBIW-LFoRCe-M²S-LiBR, Heverlee, Belgium; (3) VZWeihenstephan-TUM, Munchen, Germany; (4) Dohler GmbH, Darmstadt, Germany

The Gushing Task Force (GTF) is a scientific group of experts involved in research on the causes of primary gushing (PG). The first concern of the GTF is to reach a scientific agreement about the basic cause and origin of PG. Target 1: Consensus on physico-chemical parameters responsible for PG in order to propose the true guidelines of a standard method. 1. It's becoming more and more evident and accepted by the brewing industry that the energy needed to liberate the volume of foam from the glass container (bottle) is provided by the carbonic acid stored under two states: the one encapsulated under highly pressurized nanobubbles; the other one linked to the liquid by low energy bonds (van der Waals forces). 2. The nanobombs can only be observed if amphiphilic molecules are present in the liquid at a critical concentration, in other words "encapsulated structures of carbonic acid can only exist when hydrophobic molecules are present at sufficient concentration at the surface of the beer." 2.1. Actually, only class 2 hydrophobins were clearly purified and identified from overfoaming beer by GC-MS-MALDI-TOF spectrometry as responsible for PG. 2.2. If it is not excluded that other amphiphilic compounds present in beer it can also be responsible for PG, their exact nature and structure is still unpublished (unknown). Target 2: Inter-disciplinary scientific studies of primary gushing origins in other beverage industries (ciders, spumante, perries). Target 3: Practical trials to help the brewing industry (malting and brewing) to treat PG (based on scientific knowledge and research).

Christina Schoeberger studied brewing and beverage technology at the Technische Universität München-Weihenstephan, Germany, graduating as an engineer in 1999. She finished her doctoral thesis on "Sensory and Analytical Characterisation" in 2003. She joined the Barth Haas Group in 2005 as manager of technical sales. Since 2011 Christina has been head of the Hops Academy and since 2013 also the head of Technical Services. Within her role she is responsible for the guidance of research projects and authoring hop-related articles. Christina currently holds the position of president-elect on the ASBC Board of Directors.

21

***Fusarium* species on barley malt—Visual assessment as an appropriate tool?**

C. GEISSINGER (1), K. Hofer (2), K. Habler (3), M. Gastl (1), T. Becker (1)
(1) Lehrstuhl für Brau- und Getränketechnologie (TUM), Freising, Germany; (2) Lehrstuhl für Phytopathologie (TUM), Freising, Germany; (3) Lehrstuhl für Analytische Lebensmittelchemie, Freising, Germany

Fusarium infection in brewing cereals is a serious problem and a sign of poor malt quality. To evaluate the amount of *Fusarium*-damaged kernels, brewers and maltsters use visual assessment. Reddish discoloration is a common symptom of *Fusarium*-covered kernels caused by *Fusarium* species. In malt batches up to 5–7 red kernels per 200 g is acceptable for brewing use. Hitherto, little information has been available on the *Fusarium* species that cause these red kernels. In this study, over 50 barley malt samples were analyzed using RT-qPCR, (agar) plate cultures and visual assessment to determine which *Fusarium* species are responsible for the red discoloration of the barley kernels. In 2012 it was found that *F. avenaceum* was responsible for the red coloring of the seeds (R^2 = 0.75). However, in 2013 *F. tricinctum* was the predominant species. In 2014, both, *F. avenaceum* and *F. tricinctum* were found to be liable for the symptoms. Correlation analyses were done with the collected data. *Fusarium* DNA was not only detected in colored malt; *F. avenaceum* and *F. tricinctum* DNA could also be found in many of these practice samples which seemed to be clean. To further substantiate these results, dilution series were carried out. In these dilution series, 0 to 40 kernels infected with *F. avenaceum* and *F. tricinctum* were added to a clean, greenhouse cultivated batch to a total weight of 200 g. RT-qPCR was done on these samples; a very good correlation between the amount of red kernels and corresponding *Fusarium* DNA was found. In this study it was possible to establish a correlation between the intensity of *Fusarium* infection and the proteolytic properties of malt. In the 2012 samples, there was a significant correlation between the amount of red kernels and the Kolbach index. In 2014, however, there was a very significant correlation between red kernels and the soluble nitrogen content. From the data collected in this study, it can be established that visual assessment can indicate increased *Fusarium* contamination.

After completing an apprenticeship as a brewer and maltster at the Andechs monastery brewery (Andechs, Germany), Cajetan Geissinger studied brewing and beverage technology at the Technische Universität München (TUM), Germany. He carried out his diploma thesis at the Institute of Brewing and Beverage Technology (Prof. Thomas Becker) at TUM-Weihenstephan, where the topic of his work was "Critical Examination and Systematic Assessment of the Modified Carlsberg Test (MCT)." In 2012 he began as a Ph.D. fellow under the supervision of Prof. Becker. A significant portion of his research activities are directed toward the investigation of the influence of fungal contamination on quality characteristics in cereal processing.

22

From raw materials to malts: Influence of the malting parameters on malt aroma development

C. L. ALMAGUER (1), M. Gastl (1), T. Becker (1)
(1) TUM – Lehrstuhl für Brau- und Getränketechnologie, Freising, Germany

Malting involves the controlled germination and subsequent drying (kilning) of cereal or pseudocereal grains. By varying the processing parameters during germination and drying, a variety of malts with different attributes is obtained. The brewer's main requirement of malt is as a source of substrate, enzymes, and color; as a result traditional malting technology has developed to improve these properties. However, suitable manipulation of the malting conditions could positively enhance the aroma profile of malts as well as the sensory and nutritional properties of raw materials. Malt aroma is created based on the effects of the available combinations of amino acids and reducing sugars. These are available due to the kernel modification brought about by germination. The increased concentration of free sugars and essential amino acids provides a rich source of precursors for the key flavor generating reactions (e.g. Maillard reaction, Strecker degradation). Ultimately, the concentration and distribution of amino acids and reducing sugars in the modified grains determine the resulting aroma profile. In an attempt to understand the impact of the malting process on malt aroma development, three raw

materials (barley, rye, and quinoa) were investigated and compared. This study focused on the influence of three malting parameters (temperature, germination time, and moisture) on the analytical and sensory properties of the produced malts. The experimental designed allowed the contribution of each factor, along with their interactions, to be assessed from an analytical perspective using the appropriate instrumentation (e.g. GC-FID). Changes in the aroma profile associated with the influence of the malting parameters were determined. In addition, a standard malt was produced for each of the raw materials used. The aroma profile of the produced standard malts was determined and the key aroma compounds were identified. To determine the key aroma compounds, different analytical methods were coupled. The volatile compounds were isolated by headspace solid-phase microextraction (SPME), solvent assisted flavor evaporation (SAFE), and simultaneous distillation/extraction (SDE); these were then analyzed with GC-MS/O. Aroma extract dilution analysis (AEDA) of the SAFE extracts was done to identify the key aroma compounds of each of the produced malts. The collected data allowed accurate disclosure of the volatile compounds responsible for the rye malt aroma, quinoa malt aroma, and barley malt aroma and comparison of them among each other. Compared to other aspects in malting, little attention has been given to the aroma development in malt. Small variations in the malting process can lead to a wide range of products with very different aroma characteristics. Understanding the impact of germination on aroma properties as well as increasing the knowledge on key malt aroma compounds is essential for an informed assessment of aroma development during malt production. The maltster and brewer, in turn, may benefit from proper selection of malting parameters to add subtle aromas and flavors to beers.

In 2008, Cynthia Almaguer completed her B.S. degree in biochemical engineering at Jacobs University Bremen. She then started her master's degree in a collaborative project between the Institute of Brewing and Beverage Technology (Prof. Thomas Becker) at TUM-Weihenstephan and the Department of Food and Nutritional Sciences (Prof. Elke Arendt) at University College Cork. Her research project aimed to understand and reveal the taste and antimicrobial contributions of hop hard resins on beer. Her hop project was funded by the Barth-Haas Group. Cynthia is the 2010 recipient of the InBev-Baillet Latour Fund Scholarship for Brewing and Malting to fund her Ph.D. work. A significant portion of her current research activities are directed toward beverage development and the investigation and understanding of malt aroma.

23

Barley contributions to beer flavor I: Effect of variety, location, and genotype × environment interaction on beer flavor

D. W. HERB (1), R. C. Graebner (1), S. Fisk (1), T. Nielsen (2), D. Carey (3), T. Shellhammer (4), P. M. Hayes (1)
(1) Oregon State University, Corvallis, OR, U.S.A.; (2) Sierra Nevada Brewing Co., Chico, CA, U.S.A.; (3) New Glarus Brewing Co., New Glarus, WI, U.S.A.; (4) Oregon State University, Corvallis, OR, U.S.A.

Barley contains significant amounts of positive flavor compounds that are contributed to malt and beer; however the impact of variety and environment on barley flavor is not well understood. In this study we evaluated the beer flavor potential of three barley varieties (Full Pint; AC Metcalfe; Klages) grown in replication in three environments (Corvallis, OR, USA; St. Paul, MN, USA; Saskatoon, SK, Canada). The resulting grain was micromalted by Rahr Malting. Sierra Nevada Brewing Co. and New Glarus Brewing Co. both conducted Congress wort sensory assessments. The controls were AC Metcalfe high- and low-color malts. Gas chromatography coupled with mass spectrometry (CG-MS) at Sierra Nevada revealed that the principal volatile compounds present across samples were dimethylsulfide (759164.8 *m*/*z*), 3-methyl butanal (72583.2 *m*/*z*), 2-methyl butanal (144753.2 *m*/*z*), hexanol (129991.8 *m*/*z*), phenylacetaldehyde (393667.1 *m*/*z*), and methyl mercaptan (835.5 *m*/*z*) and contributed flavors such as fruity, floral, cooked corn, nutty, potato chips, biscuit, malty, and cereal. There were off-odors as well. Concentrations of dimethylsulfide and *trans*-2-hexanal were highest in Full Pint, while 2- and 3-methyl butanal and methyl mercaptan was highest in AC Metcalfe, and hexanal in Klages. Principal component analysis (PCA) indicated that variety and environment account for 34% and 12%, respectively, of the variation in mass-spec abundance analyte concentrations across samples. In a blind sensory assessment, panelists distinguished unique flavors and preferences across the different varieties and environments, suggesting that barley variety and production environment play a significant role in beer flavor.

Dustin Herb is a Ph.D. student of plant breeding and genetics in the Crop and Soil Science Department at Oregon State University (OSU). His research is currently focused on barley under the instruction of Patrick Hayes. Dustin's primary areas of study include genome sequencing and genomic selection, genetic mapping for low temperature tolerance, disease resistance, malt quality, and flavor compounds. Prior to starting his doctorate program at OSU, Dustin received his B.S. degree in agronomy from OSU and M.S. degree in plant breeding from Texas A&M University and was the assistant director for research at Oregro Seeds, Inc., working with forage grass, cereals, and legumes. Post studies Dustin intends to return to academia and pursue a position in malting and crop improvement, with a particular focus on brewing and distilling raw materials.

24

Influence of added commercial enzyme preparations and mashing temperature on extract recovery of laboratory malted Nigerian grown pearl millet and wheat

C. I. NNAMCHI (1), R. Agu (2), A. N. Moneke (1), F. C. Odibo (3), B. C. Nwanguma (1), B. N. Okolo (1)
(1) University of Nigeria, Nsukka, Nsukka, Nigeria; (2) The Scotch Whisky Research Institute/University of Nigeria, Nsukka, Riccarton/Nsukka, Nigeria; (3) Nnamdi Azikiwe University, University of Nigeria, Nsukka, Awka/Nsukka, Nigeria

The aim of this work was to demonstrate how different commercial enzymes and mashing temperatures of 65°C and 85°C influenced extract recovery during infusion mashing of Nigerian-grown pearl millet and wheat malts. Additionally, the effects of differences in the starch granules of the two cereal types on extract recovery were studied. Results obtained showed that wheat grown in Nigeria contained high proportions of very large-sized starch granules and reasonable amounts of small starch granules while millet contained only small granules. When mashed at 65°C, both cereal malts produced extract yields at similar levels, while mashing at 85°C increased their extracts beyond twofold. The addition of commercial enzymes during mashing of malts from both crops produced different effects. Added amylases increased extract yields of both cereals many fold at the two mashing temperatures. Added β-glucanase enzyme was more effective on millet malt than on wheat malt at 65°C despite both cereals having similar β-glucan contents. Added xylanase was more effective on wheat malt than on millet malt at both infusion mashing temperatures. Added combined β-glucanase/xylanase enzyme was more effective on wheat malt than on millet malt especially at the mashing temperature of 85°C. However, the individual enzymes produced higher levels of extracts than their combinations, a significant fact considering the immensely high cost of enzymes. Thus, the

correct and proper choice of individual enzymes such as α-amylase, β-glucanase, and xylanase rather than their combinations should produce higher extracts from the cereals. These results highlight the complex grain physiology of cereals and therefore the need for continuous research on them. In this work, α-amylase added during infusion mashing of wheat malt at 65°C gave the highest extract of 304 L°/kg (as is). Similarly, β-glucanase enzyme added during infusion mashing of millet malt at 65°C gave highest extract of 304 L°/kg (as is).

Nnamchi Chukwudi Innocent was born in Enugu, Nigeria. He obtained his B.S. degree in microbiology/biochemistry (combined honors) in 1998 and a master's degree in environmental microbiology in 2004. In 2014, he obtained a Ph.D. degree in industrial microbiology and biotechnology. His degrees all were obtained from the Department of Microbiology, University of Nigeria, Nsukka. In 2006, Chukwudi joined the Department of Microbiology, University of Nigeria, Nsukka, as an assistant lecturer. He is currently a senior lecturer in the same department. He was a visiting research fellow to the University of Leicester, England, from October 2010 to September, 2011, where he worked on the purification and characterization of peroxidases from Nigerian sorghum varieties. His current research interests include malting- and brewing-related work with using sorghum, millet, maize, wheat, and barley. Such work often includes the assessment of how key enzymes affect brewing with these grains. He is a member of the Nigerian Society of Microbiology (NSM), the American Society of Microbiology (ASM), the Society for Applied Microbiology (SFAM), and the New York Academy of Science (NYAS), among others. He has also won many awards and grants and traveled for conferences in different areas of applied microbiology in different parts of the world.

25

Overcoming pre-harvest sprout damaged malt: The effects of enzyme addition

K. L. CHRISTIANSEN (1), W. Haisch (1), R. Lahlum (1), X. Yin (2), J. McCann (2)
(1) Cargill Malt, Spiritwood, ND, U.S.A.; (2) Cargill Malt, Wayzata, MN, U.S.A.

Given the pre-harvest rains that occurred in some barley growing regions in North America in 2014, a large percentage of the malting barley crop suffered sprouting damage. While there are methods like RVA to measure germination viability, they are unlikely to predict if or when grains will lose germination energy while in storage. Decreasing germination energy negatively impacts the malting process, malt quality, and ultimately brewing parameters such as extract yield and filtration time. Germination tests and micromalting can provide some guidance for commercial malting recipes to maximize malting potential; however, it is likely there will be malt with lower enzyme activity, lower extract, and higher viscosities. This study focused on leveraging various commercial enzymes to determine the impact of the enzymes on micromalted batches with varying levels of sprout damage (40–5%) on extract, β-glucans, and viscosity. Given the poor crop, being aware of other enzymes that solubilize β-glucans in wort, it would be valuable to know what challenges are present that cannot be affected by kilning. Additionally, to understand the countering effects of enzymes that solubilize β-glucans, those enzymes were measured in selected batches. With commercial enzymes applied in germination or in the mash, the sprout damaged batches saw improvements of 1–7% increase in extract, 10–60% decrease in viscosity, and 50% plus decrease in β-glucans. Finally, while no differences in enzymes that solubilize β-glucans were observed between sprout damaged and sound kernels, differences were detected between the varieties Metcalfe, Copeland, Meredith, and Tradition.

Katrina Christiansen received a Ph.D. degree in agricultural engineering from Iowa State University in Ames in 2011. She began working with Cargill Malt as the pilot project lead in Spiritwood, ND, that same year, supervising the innovation efforts in both the pilot malting and brewing facilities.

26

Development of a GC method for the analysis of twelve key fermentation derived volatiles utilizing deuterated internal standards, SPME, and SIM

D. SEDIN (1)
(1) New Belgium Brewing Company, Fort Collins, CO, U.S.A.

The analysis of fermentation-derived volatiles can be critical for ensuring beer flavor consistency, evaluating shelf life, and troubleshooting critical off-flavors in beer. A number of methods have been developed using gas chromatography (GC) with different detectors (for example mass spectrometers [MS] or flame ionization detectors [FID]). In addition, there are a number of sample preparation techniques and different techniques for introducing the sample to the GC, including headspace injection, liquid injection, solid phase micro-extraction (SPME), and stir bar sorptive extraction (SBSE). Choosing the analytes most critical to a brewery's specific beer styles, then choosing the optimal method to conduct the analysis can be a difficult task. This talk will review the process New Belgium Brewing Company followed to develop, optimize, and validate a method for measuring fermentation volatiles. The first step was to narrow the options; this was accomplished through identifying the primary requirements for the method: high sample throughput, minimal sample preparation, compatible with instrumentation available in our laboratory, measurement of all analytes of significance for our primary brands, linear ranges to bracket all of our different brands, and a limit of quantitation (LOQ) below the flavor threshold for the key analytes. To select the analytes most critical to our beers, we utilized sensory panel data and GC-olfactometry analysis. Flavor thresholds were identified utilizing the ASBC Flavor Database. We compared different sample introduction options/parameters, sample preparation details, columns, and MS parameters. The final, optimized method utilizes deuterated internal standards, 3-phase SPME, and selected ion monitoring (SIM). The method measures 12 analytes (acetaldehyde, isoamyl acetate, isoamyl alcohol, ethyl acetate, phenethyl acetate, ethyl hexanoate, ethyl butyrate, 4-vinyl guaiacol, ethyl octanoate, decanal, 3-methyl butanal, and 2-methyl butanal). The limit of quantitation is below the flavor threshold for all analytes, and the linear dynamic range covers the concentrations found in all of our year-round beers. A full validation was completed for the method. The data are utilized to ensure process consistency, troubleshoot fermentation issues, and will be utilized for flavor matching our beers at a new brewery.

Dana Sedin is the manager of the Analytical Laboratory at New Belgium Brewing Company. He began his career in the brewing industry at Coors Brewing Company, where he held both scientific and laboratory manager positions for 10 years. He is an active member of the American Society of Brewing Chemists (ASBC) and from 2008 to 2012 held the Technical Committee chair position on the ASBC Board of Directors. Dana has a B.S. degree in chemistry from California State University, Sacramento, and a Ph.D. degree in analytical chemistry from the University of Colorado, Boulder. In 2011, Dana completed his Post Graduate Certificate in Brewing from the University of Nottingham. Outside of work, Dana's time is spent with his wife, Sarah, and daughter, Elena.

27

Beeromics: From QC to IDs of differentially expressed compounds

C. A. HUGHEY (1), C. M. McMinn (1), J. Phung (1)
(1) James Madison University, Harrisonburg, VA, U.S.A.

A robust analytical platform for untargeted differential analysis of beer samples by liquid chromatography mass spectrometry (LC/MS) was developed for the identification of compounds unique to a particular year of production or hop. The presented methodology could also be used to identify differentially expressed compounds that result from a change in a raw ingredient, a change in the brewing process, or prolonged storage. Twenty-four single-hop India pale ales (Mikkeller brewery, Copenhagen, Denmark) from two different production years were analyzed using an Agilent 6530 q-TOF-MS in positive- and negative-ion modes. A mixture of target compounds, a QC beer and an internal standard were used to monitor changes in instrument response, retention time (RT), reproducibility, and mass error. Unique molecular features (~3,000/sample) were extracted and aligned in "Mass Profiler Professional" for both the QC and Mikkeller beers. Differential analysis of the QC beer identified days that were "out of spec." Analysis of the Mikkeller beers afforded differentiation by hop and year of production; the latter yielded the greatest compositional differences. Features unique to each production year underwent MS/MS. A METLIN and literature search afforded tentative identifications. The QC beer was run in triplicate at the beginning and end of every day/work list. Target compounds were quantified in the QC beer to determine the intraday and interday RT RSDs, response RSDs, and mass error. Over the course of 13 months, the RT deviation was 3.0 s ±1.3 s, the mass error was routinely <5 ppm, and the interday response RSD was <15%. To demonstrate that the target compounds, most of which were flavonoids, adequately represented the response trends of compounds in the beer, target compound responses were compared to the summed response of features found in all QC samples (n = 54 for each polarity) above a given abundance threshold. This included 418 and 124 molecular features in positive- and negative-ion modes, respectively. Indeed, the two responses tracked quite well, thus demonstrating that unknown molecular features in a sample QC may be used to monitor instrument response. The use of external standards found in the QC, however, offers additional assurance that the QC beer does not change over time. Differential analyses of randomized Mikkeller IPAs run in triplicate were conducted based on hop, year of production, and hop year. Hierarchical clustering revealed that beers strongly clustered by year and not hop for both polarities, as IPAs produced with the same hop in different years did not cluster together. In an attempt to identify features responsible for this clustering, features unique to each production year were identified and targeted for MS/MS analysis. Exact masses and MS/MS spectra (when available) were searched against the METLIN Database. Tentative assignments were also made by comparison to the literature. Compounds such as 5-methylthioadenosine have been reported in aged beer (*Food Chemistry* 135:1284-1289, 2012) and were identified in the earlier production beer.

Christine (Chrisi) Hughey is an associate professor of chemistry at James Madison University, a predominately undergraduate institution, located in Harrisonburg, VA. She received her Ph.D. degree in analytical chemistry from Florida State University in 2002. Since 2006 she has used mass spectrometry to characterize complex food samples. In 2011, she began "beeromics" (untargeted differential analysis) out of her love for craft beer. Over time, she and her research group have developed a robust platform that can be used to answer a variety of questions of interest to brewers. At the ASBC Annual Meeting Christine aims to present this methodology in hopes of fostering industry collaborations.

28

NMR metabolomics reveals molecular details of the brewing process

A. R. SPEVACEK (1), K. L. Benson (2), C. W. Bamforth (1), C. M. Slupsky (1)
(1) UC Davis, Davis, CA, U.S.A.; (2) MillerCoors, Golden, CO, U.S.A.

Many of the macromolecular details of the brewing process have been elucidated in the several millennia that have elapsed since the first beer was brewed. However, as analytical techniques evolve in their sophistication and sensitivity, there are opportunities for delving ever more deeply into the fate of small molecules in brewing. We have used 1H nuclear magnetic resonance (NMR) metabolomics to follow the progression of the small molecules in four different beers (brewed in triplicate) at five time points throughout the brewing process. The majority of the metabolites that we identified significantly changed in concentration from the start of the boil to after secondary fermentation. In addition, we observed differences in several metabolite concentrations between dry- and late-hopped beers. These results give molecular insight into the brewing process and the effects of hops on yeast metabolism. Monitoring the small molecule profile of brews with NMR metabolomics could assist in evaluating yeast health and in early detection of bacterial contamination.

Ann Spevacek is a postdoctoral fellow in the laboratory of Carolyn Slupsky at UC Davis. She is an NMR spectroscopist who received her Ph.D. in biochemistry from UC Santa Cruz. Her research background includes metabolomics and protein structure and function. She is currently involved in a number of projects involving the metabolomics of food. She has a particular interest in applying NMR metabolomics to brewing in order to understand phenomena such as the effects of hops on yeast metabolism.

29

The evolution of CO_2 measurement within the brewing industry: What does it bring to breweries and what will be the next step?

F. VERKOELEN (1)
(1) Pentair Haffmans, Venlo, Netherlands

The world of carbon dioxide (CO_2) measurement is on the move. Conventional CO_2 measuring principles in which equilibrium pressure and temperature are measured with a manometer and thermometer, and then CO_2 content is determined with a CO_2 ruler or table are becoming obsolete. Digital technology has been introduced that allows automatic calculation of the CO_2 content. The latest development in measuring CO_2 is in the optical direction. Two examples are attenuated total reflection (ATR) for in-line CO_2 measurement and non-destructive CO_2 measurement for bottled beverages. ASBC describes standard methods of CO_2 determination and has set the standards for calculating CO_2 content; to overcome influences of temperature on the dissolved CO_2 content of a packaged beverage by controlled sample temperatures; and for compensating for the effect of foreign gases on the CO_2 content of packaged beverages by measuring headspace air and volume. Developments in CO_2 technology go further in the direction of selective CO_2 measurement that allows measurement of dissolved CO_2 without disturbance of foreign gases like nitrogen, oxygen, and/or other gasses; and CO_2 principle determining the dissolved CO_2 result independently of the beverage temperature by recalculating the CO_2 content to a standardized temperature, e.g. 20°C. What did all these changes bring the breweries and what is the next step—total packaged CO_2 (TPCO)?

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 CO_2 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.

30

Hard resins: The complementary bitter fraction present in hops, pellets, and ethanol extract

M. BIENDL (1), F. Schuell (2), S. Cocuzza (3)
(1) Hopsteiner HHV GmbH, Mainburg, Germany; (2) Lehrstuhl Brau- und Getraenketechnologie, Freising-Weihenstephan, Germany; (3) Simon H. Steiner, Hopfen, GmbH, Mainburg, Germany

The commercial value of hops is particularly influenced by the content of α-acids, the main source of bitter taste in beer. Only recently could the additional positive contribution of hard resins to beer bitterness be clearly demonstrated after isolation of more than 30 single constituents from this fraction with subsequent confirmation of their bitter sensory profile (thesis of Michael Dresel, 2013). Based on spiking experiments in the laboratory, at least 20% of the hop-derived beer bitter intensity was attributed to hard resins and around 75% to iso-α-acids. Now the goal was to verify the practical impact of these findings by comparing the bitterness impressions resulting from different hard resin-containing hop products in brewing trials (6 hL). Single-hopped lager beers were produced in duplicate using pellets, ethanol extract, or a special product, enriched in hard resins, all from the hop variety Hallertau Taurus, crop 2013. The beers were evaluated by chemical (LC-MS/MS and GC-MS) and sensorial (two trained panels) analyses. Single constituents like xanthohumol, isoxanthohumol, or co-multifidol glucoside, which are typical for the hard resin fraction, were present in all the different beers. Their concentrations were almost identical in the case of pellets and ethanol extract but at least a factor of three higher in the case of the hard resin-enriched product. However, the taste panels detected no significant differences between the various beers, even when the so-called "duo/trio test" was performed. The fact that the variant of using the special product also resulted in comparable quality confirms a positive impact of hard resins. This product was the residual bitter fraction after re-extracting ethanol extract with supercritical carbon dioxide. It contained the whole range of hard resin constituents that are carried over from hops, pellets, or ethanol extract during the brewing process. Thus their beneficial influence on the bitter taste of beer could be verified in this study. Moreover, this fraction consists of single compounds supporting the positive image of beer with regard to health aspects as, for example, recently discussed in the scientific paper "American India Pale Ale Matrix Rich in Xanthohumol is Potent in Suppressing Proliferation and Elevating Apoptosis of Human Colon Cancer Cells" (published in 2014). Considering both their contribution to the bitterness and to the health image of beer makes it evident that evaluating the hard resins as an important hop fraction has value for the brewing industry.

Martin Biendl is a chemist (Ph.D. degree in 1990) and R&D manager at the German site of the global Hopsteiner group, a hop trading and processing company. He is the representative of the International Hop Industry Cooperation (IHIC) on various analysis committees of the international hop and brewing industry and he is a board member of the German Hop Trade Association.

31

Direct ESI-MS quantitation of bittering acids, isomerization, and oxidation products in hops and beer for calculation of the hop storage index and international bitterness units

G. HASMAN (1), A. Venter (1)
(1) Western Michigan University, Kalamazoo, MI, U.S.A.

A new direct analysis mass spectrometric method is demonstrated to simultaneously quantitate the α- and β-acid content, as well as the isomerization and oxidation products, of the hop acids in hop or beer samples. The bittering potential of hops can be attributed to isomerization of the hop acids and other non-isomerized hop acid products. The total bitterness in beer is usually measured in international bitterness units (IBU). The bitter non-isomerized hop acid products are typically due to oxidation, which is measured by the hop storage index (HSI). The HSI measures the decrease of α- and β-acids due to oxidation that occurs during storage, which can reduce the isomerization bittering potential of the hops but also lead to additional bittering due to the bittering potential of oxidized hops when dry-hopping beer. Typically, HSI is measured by UV-VIS as the ratio of absorbencies of two wavelengths corresponding to the oxidized and non-oxidized bittering acids. Standard HPLC-UV methods (e.g. ASBC Hops-14) generally do not measure the hop storage index. Here, we present an alternative method for the quantification α- and β-acids and their oxidation products in hops pellets, bracts, and extracts for the calculation of bittering potential and HSI. The same method can also be applied to beer samples to measure isomerization products and oxidized α-acids, for the calculation of IBUs in beer. The proposed method uses direct analysis by electrospray ionization mass spectrometry of prepared samples to calculate bittering potential, HIS, or IBUs and other sample attributes in less than 1 minute. Hop standards were force oxidized at 80°C for 48 hours or subjected to direct sunlight for up to 21 days. Calculation of oxidation product concentrations in the standard was based on the assumption of complete oxidation, as verified by ultra-high performance liquid chromatography mass spectrometry (UPLC-MS). The α-, β-, isomerized, and oxidized bittering acids were measured by loop injections and analyzed by ESI-MS without chromatographic separation. The components were quantitated by external calibration after serial dilution of the force oxidized standards. The HSIs were calculated by the ratios of the sums of the mass percentages of the bittering acids and oxidation products and compared to the UV-Vis calculated HSI values. Similarly IBUs were calculated based on measured iso-α-acid and oxidation product concentrations and compared to standard methods for IBU determinations.

Gregg Hasman, Jr. studied chemistry at Michigan Technological University (Houghton, MI), where he received his B.S. degree in chemistry in 2011. He taught Studio Chemistry Lab I and II from 2010 to 2012 under the guidance of Paul Charlesworth at Michigan Technological University. Gregg is currently in his third year of the Analytical Chemistry Ph.D. program at Western Michigan University (Kalamazoo, MI) studying under Andre Venter. In mid-2013, Gregg supervised the start-up of the hops testing facility at Western Michigan University, which offers standardized hop analysis according to the official methods of analysis of the American Society for Brewing Chemists (ASBC). Gregg's current research involves the development of novel methods of hops analysis using electrospray ionization mass spectrometry to rapidly quantitate and identify characteristic components within various breeds of hops.

32

The influence of mode of dry hopping on flavor stability of dry-hopped beers

C. SCHOENBERGER (1), M. Zunkel (2), S. Hanke (3), U. Wellhoener (4), E. Beck (4), A. Gahr (5)
(1) Barth Innovations, Stuttgart, Germany; (2) Barth Innovations, Nuremberg, Germany; (3) Bitburger Braugruppe, Bitburg, Germany; (4) Boston Beer Company, Lehigh, PA, U.S.A.; (5) Hopfenveredlung St. Johann, St. Johann-Train, Germany

Dry hopping can be carried out in many different ways. Important parameters in this context are: 1) Is dry hopping done in a static or dynamic way? 2) Is yeast present during dry hopping—and does this make a difference? 3) What is the influence of pasteurization of dry-hopped beers. In this study all 3 parameters where investigated and 12 different beers where brewed and compared. The fresh beers revealed noticeable sensory differences depending on parameters 1–3. These beers where stored for 6 months at 2 different temperatures to monitor the flavor changes and to see how the different parameters influence the flavor stability of these dry-hopped beers over time.

Christina Schoenberger studied brewing and beverage technology at the Technische Universität München-Weihenstephan, Germany, graduating as an engineer in 1999. She finished her doctoral thesis on "Sensory and Analytical Characterisation" in 2003. She joined the Barth Haas Group in 2005 as manager of technical sales. Since 2011 Christina has been head of the Hops Academy and since 2013 also the head of Technical Services. Within her role she is responsible for the guidance of research projects and authoring hop-related articles. Christina currently holds the position of president-elect on the ASBC Board of Directors.

33

Key aroma compounds in 'Centennial', 'Citra', and 'Nelson Sauvin' hop identified by aroma extract dilution analysis

S. Feng (1), Y. P. Qian (1), M. C. QIAN (1)
(1) Oregon State University, Corvallis, OR, U.S.A.

Hops (*Humulus lupulus* L.) are considered the most important ingredient in brewing since they contribute the characteristic aroma and flavor to beer. However, the chemical compounds responsible for the hoppy aroma have not been well understood due to the complexity of hop composition. With the increased interest in dry hopping and aroma hops in the industry, it is important to understand the aroma composition of hops. The aroma compounds in 'Centennial', 'Citra', and 'Nelson Sauvin' hop varieties were investigated in this study. The hops were extracted with dichloromethane followed by solvent assisted flavor evaporation (SAFE) to remove the non-volatile components. The volatiles were further pre-fractionated on a silica gel column into non-polar and polar fractions. Aroma extract dilution analysis was performed for both fractions. The odor compounds were identified by GC/Olfactometry-MS, retention indices, and two-dimensional GC-MS/olfactometry. Although different hop varieties had different aroma profiles, the compounds with high FD values in all three hop varieties were geraniol, 3-methylbutanoic acid, linalool, vanillin, and myrcene. The isomeric ratio of linalool was further investigated on two-dimensional GC-MS. It was found that the (R)-linalool was dominated in all three hop varieties (92–96%); however, during the beer making process, some of the (R)-linalool were converted to (S)-linalool, which has a much higher sensory threshold. The (R)/(S)-ratio of linalool in some commercial beers were further studied and the (R)-linalool ranged from 80% to 93%. This conversion was minimal during the dry-hopping process.

Michael C. Qian is a professor of flavor chemistry at Oregon State University and chair of the Food and Agricultural Food Chemistry Division of the American Chemical Society (2014). He received his Ph.D. degree from the University of Minnesota under the guidance of Gary Reineccius. Michael's research interests at Oregon State University cover aroma/flavor chemical/biochemical generation in dairy products, small fruits (blackberries, raspberry, and strawberry), wine and wine grapes, beer, and hops. He has published many research papers, including 12 book chapters and 4 books in the field of flavor chemistry, and is a frequent speaker at national and international meetings. In 2014, Michael was named a Fellow of the Agricultural and Food Chemistry Division of the American Chemical Society.

34

Very high gravity brewing: Effects of the processes on fermentation in 30°Plato wort

Y. MURAOKA (1), T. Kurihara (1), S. Tamura (1), T. Nakamura (1)
(1) Frontier Laboratories of Value Creation, Sapporo Breweries Ltd., Yaizu, Japan

Many breweries make use of high gravity brewing (HGB) to increase productivity without expanding existing brewing facilities and to save energy. However, HGB has a number of disadvantages. One of the major problems is poor fermentation performance, mainly because of osmotic and ethanol stress on brewing yeast during fermentation. To overcome this problem, various yeast nutrient supplements such as fatty acids, sterols, free amino nitrogen, and so forth, have been used to maintain yeast performance under stressful conditions. Furthermore, the improvement of fermentation has also been attempted through aeration during fermentation. However, this method is time-consuming; it takes about 2 weeks to complete fermentation. In this study, we investigated whether fermentation efficiency can be improved by combining agitation and aeration in a 2.8 L scale fermentation test using 30°Plato wort. This wort was prepared by the addition of corn syrup to all-malt 12°Plato wort. We used bottom-fermenting yeast. Agitation was carried out throughout the fermentation period. Aeration was conducted for 4 days of fermentation. As a result, we concluded that it was possible to produce up to 11% (v/v) ethanol by both agitation and aeration within about 1 week. We measured free and esterified ergosterol content in yeast cells at the end of fermentation. The esterified ergosterol content of yeast with both agitation and aeration was increased compared to when either one of these processes was performed independently, although the amount of free ergosterol was similar among those. Free ergosterol is localized at the plasma membrane, while esterified ergosterol is stored within the lipid granule. It is reported that free ergosterol contributes to the ethanol tolerance of yeast cells. From these results, it was assumed that very high gravity brewing fermentation could be achieved within a shorter period of time, not because free ergosterol improved the ethanol tolerance of yeast, but because yeast grew effectively through the synergy of agitation and aeration.

Yasuhiro Muraoka received an M.S. degree in biological sciences from the Nara Institute of Sciences and Technology. He joined the Hokkaido brewery of Sapporo Breweries Ltd. in 2005 as a brewing engineer. Since 2010, he has been working in the Frontier Laboratories of Value Creation as a lead brewer.

35

Monitoring of industrial ale and lager brewing fermentations

A. SPEERS (1), M. Josey (1)
(1) ICBD- HWU, Edinburgh, U.K.

The logistic model has been used to fit and predict the decline of wort density in both industrial and laboratory data since 2003. This four-parameter sigmoidal (s-shaped) function fits the decline in apparent extract using a non-linear regression technique and now forms part of ASBC Yeast-14: The Miniature Fermentation Assay. While this logistic model has been shown to fit industrial and laboratory fermentations (MacIntosh, et al. 2012 and 2014, J. ASBC; and Speers et al. 2003 and 2006, J. Inst. Brew.) it would be useful to predict the error of these fits. Prediction intervals (PI) are defined as estimated ranges where future observations will fall above and below the curve. When constructed, these intervals can serve as the equivalent of upper and lower control limits used in univariate control charts. As such, PI values would be a useful addition to the brewing statistical process control (SPC) tool kit. Our objective was to examine data from industrial lager and ale brewing fermentations to see how PIs could be simply constructed. If variance throughout the fermentation is constant (or is homoscedastic) then PIs can be easily calculated via use of Graphpad Prism software. However, if the variance of the data varies with time (or is heteroscedastic) then calculation becomes more difficult. However, PIs can be estimated when repeated fermentation data at fixed fermentation times is available. With fixed fermentation time data, the calculation of sample standard deviations (SD) is possible. Then, one can estimate (at each time), the upper interval (+3SD), the mean, and the lower interval (–3SD). These three curves (i.e., the upper control limit, mean, and lower control limit) can be fit by the logistic model producing an estimate of the change in apparent extract as well as an estimate of the heteroscedastic PI. Examination of the both the lager and ale fermentations revealed that the fermentations were heteroscedastic with a low variation at the beginning and end of the fermentation and a wide variation at the midpoint of the fermentations. However, the data was not measured at fixed interval times precluding the PI estimation technique discussed above. To allow for estimation of apparent extracts at random fermentation times the logistic model was used to fit to individual fermentations thus producing a data set at fixed times. This then allowed estimation of a heteroscedastic PI as discussed above. In examining the ale fermentation, a 99.7% confidence prediction interval made assuming homoscedastic data excluded 4.3% of the data indicating an overly conservative interval. When using the method of 99.7% confidence prediction interval construction assuming hetroscedasticity only 0.33% outliers occurred. With this technique brewers now can produce fermentation prediction intervals which can be used in an analogous method to univariate control charts to help control fermentations.

Alex Speers is a professor and the director of the International Centre of Brewing and Distilling at Heriot Watt. Previously he was a professor in the Food Science program at Dalhousie University. Born in Creston, BC, Canada he gained B.S. (Agr.), M.S., and Ph.D. degrees at UBC in Vancouver, Canada. In the past, Alex has been employed in the Quality Assurance Departments of both Labatt and Molson Breweries. His research interests include various aspects of the brewing and distilling process, including fermentability, yeast flocculation, fermentation modeling, extract calculations, and the properties of (and problems created by) barley malt. He has organized, presented, or judged at brewing events in America, Australia, Canada, China, and Ireland. Alex has spent sabbaticals at CUB/Fosters and the Columbia Brewing Company. He is a past chair of the Editorial Board of the MBAA Technical Quarterly. *Alex belongs to several professional societies and is a member of the editorial boards of the* JASBC, JIB*, and the* TQ. *He has published or presented more than 200 papers, is a Fellow of the Institute of Brewing and Distilling, and is a Chartered Scientist. In 2011 he received the W.J. Eva Award from the Canadian Institute of Food Science and Technology.*

36

Analysis of sugar attenuation with a curve-fitting method and its application for industrial fermentation control

T. IRIE (1), Y. Ito (1)
(1) Asahi Breweries, Ltd., Moriya, Japan

In industrial brewing, we can obtain much information from the sugar attenuation profile during fermentation. We've made some indices from the profile to monitor the yeast activity and to provide the appropriate feedback to the next fermentation condition. Even with the practical larger scale they could help us to optimize the quality of our products. In this study, we examined a curve-fitting method to analyze the attenuation data in beer fermentation. By curve-fitting with a last square method, we could approximate a series of apparent extract data by a certain shape of model curve. And from the function of the model curve we could obtain information about attenuation rate with a mathematical method. We investigated whether this method would be useful for analyzing fermentation also on the industrial scale. We used some kinds of S-shaped (sigmoidal) curves with several parameters to fit a series of attenuation data in beer fermentation. Some of these curves showed good fitness ($R^2 > 0.97$) even to the data from the large scale fermenter (2,000–5,000 hL). From each result curve we picked up some critical points, such as an inflexion point, and also calculated some values, such as attenuation rate, at the point. We analyzed the fermentation data for various beer brands in our several breweries through all seasons. The result from this analysis with various brewing conditions suggested that the shapes of these fitting-curves would change depending not only on beer characters such as row material composition and original gravity of wort, but also on the variety of brewing conditions in our different breweries. And the parameters from the curve function would help us to describe the fermentation features in each brewery and make a strategy to optimize fermentation quality regardless of brewery. We also made a hypothesis that the critical point for the attenuation would correspond to the changing point for the growth phase of the yeast, and from the fitting-curve we could monitor the period of the phase change. From this point of view we will discuss some examples that we used for these critical points as new milestones for controlling the formation of some aroma compounds which have important roles for beer quality, such as esters and sulfur compounds.

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.

37

Study on proanthocyanidins-rich beer

Y. Song (1), W. Zhao (2), G. ZHOU (1)
(1) Qilu University of Technology, Jinan, China; (2) Tianjin University of Science and Technology, Tianjin, China

Proanthocyanidins are a large family of phenolic compounds. Recent studies have shown that proanthocyanidins are antioxidative, anti-inflammatory, anti-hypertensive, and hypocholesterolemic. Regular consumption of proanthocyanidins may decrease the risk of cardiovascular diseases, cancer, and neurodegenerative diseases. However, the content of proanthocyanidins in common beer is low. Their main sources are malt and hops. *Lycium ruthenicumm* Murr, which grew only in Tibet China, had a much higher proportion of proanthocyanidins than hops and malt and it could be used as part of the raw material for beer brewing to increase the proportion of proanthocyanidins in beer. In this study, 5% of *L. ruthenicumm* was used as raw material to brew lager beer with 12°P. Results showed that the content of proanthocyanidins was increased from 48 mg/L to 103 mg/L in wort and from 22 mg/L up to 49 mg/L in final beer. The total content of polyphenols in beer was improved from 86 mg/L to 149 mg/L. Finally, DPPH and hydroxyl radical scavenging activity assay showed that the antioxidant activities and free-radical scavenging activities of high-proanthocyanidin content beer was significantly higher than that of control beer, which is beneficial to human health and can even significantly improve beer flavor stability.

Guangtian Zhou teaches at the School of Biological Engineering, Qilu University of Technology. Guangtian is the commissioner of Standardization Administration of the Peoples Republic of China and director of the Shandong Society for Microbiology. Guangtian has hosted nine international beer beverage technology seminars in China and published seven monographs and two translations on beer.

38

The effects of polyphenols extracted during dry hopping on beer flavor stability

B. M. TITUS (1), A. Oberholster (1)
(1) UC Davis, Davis, CA, U.S.A.

The phenolic profiles of barley, hops, and beer have been quantified in past research and their interactions with flavor-active compounds in beer has been documented by many researchers, but this work is far from exhaustive. Little is known about the composition of the compounds that influence the antioxidant behavior of hops and beer. Very few studies have documented the extraction of hop-derived compounds specifically during dry-hopping while monitoring the effects of this process on beer flavor stability. It is important to understand the origins of antioxidant compounds in beer as they have been shown to contribute significantly to beer quality and stability over time and they prevent the deterioration of flavor-active compounds in beer. Control of the concentration of these compounds in beer can not only increase the shelf life of the beer, but it can also have significant effects on the colloidal stability of the beer. The combined positive effect that polyphenols exhibit on beer flavor stability and the potential negative effect on colloidal stability make them a dichotomous set of compounds that require careful consideration. The objectives are 1) to determine the impact of dry-hopping on the flavor stability of beer in relation to polyphenol extraction; and 2) to determine the extraction rates of hop-derived flavor-active compounds during dry-hopping. The methods used include beer brewing: all experimental beers will be brewed at the August A. Busch III pilot brewery on the UC Davis campus in Davis, CA, and dry-hopped for a duration of up to 4 days. Iso-α-acid analysis: modified SPE-HPLC/DAD analysis as described in Jaskula et al. (2007). Polyphenol analysis: SPE-HPLC/DAD analysis as described in Dvořáková et al. (2007). Carbonyl analysis: modified HS-SPME/GC-MS analysis as described in Saison et al. (2008). Descriptive analysis: sensory analysis will be performed on selected treatments by a trained panel of 15 individuals. Analysis will be done on fresh beer and on the same beer aged for 2–3 months. This research is in progress. The results of this original research will provide data increasing our understanding of the extraction of flavor-active compounds during the dry-hopping process. A positive correlation of chemical and descriptive analyses will provide strong evidence of the preservative effects that hop-derived polyphenols contribute to beer as well as build on the current body of research in the fields of polyphenols and beer flavor stability. This research will provide the industry with a better understanding of the contribution made by polyphenols to beer flavor while elucidating the role of the dry-hopping process in flavor stability. As breweries continue to employ the dry-hopping process for a growing number of their beers, the importance of research in the field of hop chemistry increases.

Brad Titus is a graduate student working toward an M.S. degree in the field of agricultural and environmental chemistry at the University of California, Davis. His research focuses on hop chemistry and beer flavor stability, and he is currently working under Anita Oberholster. Brad also completed his B.S. degree at UC Davis in food science and technology, with an emphasis in brewing. He has been involved in the Food Science Brewing Club at UC Davis as an officer since the club's inception.

39

A novel beer fining and stabilizing agent extracted from hops

D. J. COOK (1), K. Westwood (2), R. S. Linforth (1)
(1) University of Nottingham, Loughborough, U.K.; (2) Barth Innovations Ltd., Paddock Wood, U.K.

Fining agents are used in the clarification of beers to reduce the time required to sediment suspended yeast cells and ensure the colloidal stability of beer. Here we describe the production and characterization of a novel fining agent extracted from hops—a natural ingredient used in the brewing process. This can be used in brewing instead of isinglass, with the advantages that it is kosher and vegan friendly. Not only does it flocculate yeast efficiently, it also takes out chill-haze. The objective was to demonstrate the feasibility of extracting and preparing a fining agent from hops and to characterize its performance. A rapid assay to appraise the yeast-fining activity of hop extracts was developed and used to screen extracts of both native hop cones and spent hops (from commercial extraction with either CO_2 or ethanol). Several commercially significant hop varieties were screened. The influence of extraction solvent and conditions such as time, temperature, and pH were also investigated. Following optimization of the extraction process hop extracts were compared to a commercial isinglass preparation for their fining activity and effectiveness in reducing chill-haze in both ale and lager style products. The results showed the active material could be extracted from both intact hops and spent hop material and was present in all eight spent hop samples investigated (Galena, Summit, Zeus, Target, Magnum, Hallertauer Magnum, Hallertauer Herkules, and Hallertauer Taurus). Extraction using 70% acetone (aq) generated the purest, most active form of product with an indicative dose rate to fine beer of 16 mL/L at 4°C, as compared with 12 mL/L of commercially sourced isinglass. Approximately 20 g of spent hops generated sufficient extract to treat 1 hL of beer, on which basis there are more than enough spent hops produced annually to meet global demands for fining agents in brewing. The active component is a proanthocyanidin. These polyphenolic compounds occur in many plant types, are known to

stick to yeast cells, and are associated with antioxidant activity. The proanthocyanidins extracted from hops are of sufficient size to be potent yeast-flocculating agents, effecting rapid fining of suspended cells. Moreover, within the optimal dose range, hop extracts were active against chill haze and matched the action of isinglass in this regard in the beers tested. When used to treat beer in maturation, or under cask conditions, the finings formed a compact sediment which was not easily disturbed and should ensure that beer losses are minimized. The feasibility of preparing a novel fining agent from hops has been demonstrated. Preliminary data indicate that addition of the finings at an optimal dose rate has minimal impact on the organoleptic properties of beer. Brewing trials to determine the potential impacts on the properties and stability of beer in-pack are ongoing and will be reported at this meeting.

David Cook is an associate professor in brewing science at the University of Nottingham, U.K. David holds a B.S. (honors) degree in chemistry and food science (Reading) and a Ph.D. degree in flavor technology (Nottingham). David has 20 years of experience conducting research and teaching related to brewing, analytical food chemistry, and flavor technology. He is the course director for the innovative e-learning–based master's degree courses in brewing science at Nottingham. His group is engaged in collaborative research with industry across the malting and brewing sectors, with current projects focused on malting science and technology, beer flavor quality and stability, and the reduction of primary energy usage in malting and brewing.

40

Origin of hydrophobins and the constant "k" in Henry's Law govern the volume of foam formed by primary gushing of beer

G. S. Derdelinckx (1), M. POSTULKOVA (2), K. Cordova (3), D. S. Riveros Galan (4), H. Verachtert (1), K. Gebruers (5), S. Smet (6), S. M. Deckers (7), H. Neven (8)
(1) KULeuven-FBIW-LFoRCe-M²S-LiBR, Heverlee, Belgium; (2) KULeuven-FBIW-LFoRCe-M²S-LiBR, Heverlee, Czech Republic; (3) KULeuven-FBIW-LFoRCe-M²S-LiBR, Heverlee, Mexico; (4) KULeuven-FBIW-LFoRCe-M²S-LiBR, Heverlee, Colombia; (5) KULeuven-FBIW-LFoRCe-M²S-CLMT, Heverlee, Belgium; (6) KULeuven-FBIW-M²S-COK, Heverlee, Belgium; (7) Brewery of Orval, Florenville, Belgium; (8) Brewery Duvel/Moortgat, Breendonk, Belgium

Primary gushing of beer is basically most often related to microbial contamination of raw materials such as barley and malt by typical fungi. Moreover it has been demonstrated since 2006 that, depending on the mold involved, the amount of the proteins (the class II hydrophobines) responsible for primary gushing (expressed in volume) is variable. However it remains to be underlined that the major responsible molecule of "primary gushing" is in fact CO_2 (as also for "secondary gushing"). After opening of a bottle (decapping), the overfoaming (liquid expulsion) by "primary gushing" occurs in two phases: at first, over-pressurized nanobubbles (nanobombs) contain CO_2 and they explode. This generates shock energy which reaches the glass wall of the bottle. This phenomenon was studied by Rodriguez who showed that the hydrogen bonds (low energy) between CO_2 and beer can be disrupted consecutively to a developing cavitation movement. Finally, after the onset of this reaction the quantity of liquid expelled out of the bottle represents the difference between the energy liberated by the cavitation, the resistance of the hydrogen bonds, and the volume taken by the liberation of the CO_2 under gaseous form! Quantitatively (regarding the volume of the bottle), the latter is clearly the most important. Qualitatively, it would be a good improvement to reduce gushing should it be possible to improve (increase) the binding between CO_2 and the beer matrix in a beer susceptible to primary gushing. This link is in fact under the governance of the law of Henry and more precisely of the constant "k." This constant varying in function with temperature (!) establishes the solubility of gaseous CO_2 in liquids in function with the pressure. As indicated, the bonding between CO_2 and water is based on van der Waals forces and lowering the temperature can play an important role by helping the stability of the structure. In specialty beers with a complex structure, CO_2 can be more or less linked depending on the raw materials that are used by the recipe. In those beers, also depending on the brand characteristics (ale or lager for example), the use of an identical malt can be done without risks or provoke detrimental consequences after selling the beer. This all depends on the consumption (dispensing) conditions and on the aspects of the constant of Henry.

Michaela Postulkova (born 1987) holds an M.S. degree in biotechnology (2012) obtained at the University of Chemistry and Technology (UCT), Prague. She has been studying brewing and malting technology with a focus on the problem of gushing in beer. Michaela has been pursuing a Ph.D. degree in the Department of Biotechnology (UCT) in the group of Assoc. Prof. Branyik since 2012, and in 2013 she started working at the Czech Academy of Science, in the Institute of Chemical Process Fundamentals. Since 2014, she has been an intern in the group of Prof. Derdelinckx in KU Leuven, Belgium. Her field of studies is two-phase systems, which includes foam and foaming, with special attention on gushing in beverages.

41

Optimization of kilning conditions for multiparameter equilibrium of malt using response surface methodology

S. HUANG (1), J. Yu (1), W. Fan (1), J. Dong (1), H. Yin (1), J. Lu (2), S. Hu (1), J. Liu (1), S. Huang (1)
(1) State Key Laboratory of Biological Fermentation Engineering of Beer, Tsingtao Brewery Co., Ltd., Qingdao, China; (2) School of Biotechnology and Key Laboratory of Industrial Biotechnology, Jiangnan University, Wuxi, China

The kilning process is a key process for final malt quality which is balanced by various positive and negative parameters. In this paper, the influence of kilning conditions on malt quality related to malt lipoxygenase (LOX), malty aroma, flavor stability, and sensory evaluation was investigated using response surface methodology (RSM). Micro-malting (1 kg) trials were conducted with Gairdner barley. A Box-Behnken factorial design with three factors and three levels was used for fitting a second-order response surface. The results indicated that the minimum value (3.36 U/g) of LOX activity was obtained when the kilning temperature, kilning time, and withering time were 90°C, 3.0 h, 14 h respectively, and were especially greatly affected by kilning temperature and withering time. The content of HDMF (4-hydroxy-2, 5-dimethyl-3 (2H)-furanone), TBZ value, and stale flavor aldehydes clearly increased with the rise of kilning temperature and the extension of kilning time and withering time. Second, the corresponding second-order mathematical models were established for predicting each parameter. Among them, P values of model equation of LOX activity, nonenal potential, HDMF, TBZ, methional, and furfural were 0.0303, 0.0301, 0.0402, 0.0037, 0.0103, and 0.0191, respectively, and R^2 values were 0.9165, 0.9168, 0.9054, 0.9658, 0.9475, and 0.9317, respectively, which indicated that F examination showed highly significant relativity for regression equations ($P < 0.05$) and data in excess of 90% could be well explained ($R^2 > 0.88$). Finally, setting the goal of minimizing LOX activity, nonenal potential, TBZ, methional, and furfural and maximizing the content of HDMF, we carried out optimization of the kilning process by balancing the above six positive and negative parameters and the optimum kilning conditions were obtained. The optimum kilning temperature, kilning time, and withering

time were 86.56°C, 3.14 h, and 14 h, respectively. These results offer understanding of the influence of kilning conditions on malt quality and provide technological guidance for malting plants.

Shuxia Huang was born in 1977 and obtained her M.Eng. degree from Qilu University of Technology (Jinan, Shandong Province, China) in 2004. She then joined Tsingtao Brewery Co., Ltd. and took up research and development work related to beer brewing. She began her doctoral program at Jiangnan University (Wuxi, Jiangsu Province, China) in 2013. Her research focus is on beer flavor stability, particularly lipid oxidation of malt, and brewing procedures, as well as beer foam stability.

42

Establishing a new quantitative method for *Fusarium* hydrophobins using LC/MS/MS

K. INOMOTO (1), N. Doi (1), S. Masuda (1), M. Aizawa (1)
(1) Asahi Breweries, Ltd., Ibaragi, Japan

Hydrophobin, an amphiphilic low-molecular protein produced by filamentous fungi that infect barley and malt, is the direct cause of beer gushing. Hydrophobins produced by *Fusarium* fungi are especially known for their tendency to induce gushing in beer. It has been reported that, in beer, ~3 µg/L of such hydrophobins can cause gushing (Sarlin, T., et al. J. Inst. Brew., 111:105, 2005). To evaluate the gushing potential more accurately, the hydrophobins need to be quantified with higher specificity. Previously, papers reported measurements performed by the ELISA method using polyclonal antibody (Sarlin, T., et al. J. Inst. Brew., 111:105, 2005). However, since it does not quantify hydrophobin proteins with high specificity, a highly specific quantification method is desired. Thus, in this research, to analyze hydrophobins with higher accuracy and specificity, we established an analytical method that specifically quantifies hydrophobins derived from *Fusarium* fungi in beer and malt using liquid chromatography/triple quadrupole tandem mass spectrometry. A multiple reaction monitoring method was designed, using the target peptide fragments derived from hydrophobins that were detected after pre-treatment via enzymatic digestion and solid-phase extraction. This allowed for highly sensitive analyses with a detection limit of several µg/L for beer and less than 1 µg/g for malt. Malt samples that exhibited different gushing propensities in the gushing test were analyzed using our method. Results showed that malt samples with high hydrophobin content had a tendency to exhibit gushing. This indicated that our method has the potential to be useful for predicting gushing potential in malt and beer.

Kumiko Inomoto joined Asahi Breweries, Ltd. in 1986. She has been involved in analytical chemistry research for 20 years. She is now in the Department of Flavor and Chemical Analysis Research Laboratories for Alcohol Beverages.

43

Identifying the protein molecular weight distribution of different malting barley varieties by capillary gel electrophoresis

J. YU (1), J. Liu (1), W. Fan (1), J. Dong (1), S. Hu (1), S. Huang (1), S. Huang (1), H. Yin (1)
(1) State Key Laboratory of Biological Fermentation Engineering of Beer, Tsingtao Brewery Co. Ltd., Qingdao, China

It is well-known that the protein components of malting barley are correlated with barley variety and growing regions. This study examined the differences in protein molecular weight distribution (PMWD) among 18 malting barley varieties by capillary gel electrophoresis with 26 samples of 8 Canadian malting barley varieties (CDC Copeland, AC Metcalfe, CDC Meredith, Newdale, Legacy, AC Bountiful, Sister, and Select) and 9 Australian malting barley varieties (Baudin, Gairdner, Schooner, Commander, Sloop, Vlamingh, Flagship, Hindmarsh, and Hamelin). The test results showed that there were some significant differences in protein molecular weight distribution between Canadian and Australian malting barley. The proportion of high molecular weight protein (e.g. 50–100 kDa molecules) for Canadian barley (16.74%–46.06%) was significantly higher than that for Australian barley (4.26%–16.16%). And the proportion of low molecular weight protein (e.g. less than 10 kDa molecules) for Australian barley (23.53%–41.86%) was significantly higher than that for Canadian barley (12.28%–32.54%). On the other hand, the PMWD of difference among the Canadian varieties was recorded: CDC Copeland's PMWD was similar to AC Metcalfe, and the 50–100 kDa protein proportion for the two varieties was highest among the 18 malting barley varieties. However, the proportions of 10–20 kDa, 20–50 kDa, and 50–100 kDa for AC Metcalfe and CDC Meredith were 31.6%, 16.01%, and 40.28% and 40.91%, 11.78%, and 16.74%, respectively. Compared with SDS-PAGE, the capillary gel electrophoresis has better resolution and accuracy, as well as higher degree of automation; this method could be used for screening barley varieties with high molecular weight protein, which offers better beer foam stability, and for the identification of malting barley varieties.

Junhong Yu is a vice director of the R&D Center of Tsingtao Brewery Co. Ltd. She obtained her doctor of science degree from the Ocean University of China in 2001. She joined Tsingtao Brewery Co., Ltd. in 1997 after obtaining her M.Eng. degree from Jiangnan University in the same year, and began her 17 year research career. Her research interests focus on beer foam and colloid stability, protein analysis, lipoxygenase (LOX), starch-degrading enzymes, etc. She attended the ASBC Annual Meeting in 2007 to give an oral presentation and WBC 2012 to present a poster.

44

Development of a detection method and occurrence of citrinin in corn and rice from China

S. C. Pei (1), Y. P. Zhen (1), J. W. Gao (1), Y. Li (1), W. J. LEE (2)
(1) Qiqihar University, Qiqihar, China; (2) Gangneung Wonju National University, Gangneung, Korea

Citrinin (CIT) is a fungal metabolite and a common food contaminant which can cause the deterioration of liver or kidney function in animals. Corn and rice used in the brewing process have frequently been reported to be contaminated with fungi. In some countries, beer samples have been reported to be contaminated with a high concentration of CIT during the summer season. In this study, CIT protein conjugate antigen was prepared with bovine serum albumin (BSA), ovalbumin (OVA), and keyhole limpet hemocyanin (KLH) using CIT-BSA, CIT-KLH, CIT-OVA, CIT-DCC-BSA, and CIT-DCC-OVA. Titration results showed that only anti-CIT-KLH serum highly combined to CIT-BSA conjugate and CIT. The linear range for the developed indirect competitive ELISA was 1–100 µg/kg of CIT concentration, and the limit of detection for CIT was 0.1 µg/kg. Half maximal (50%) inhibitory concentration (IC_{50}) of the anti-CIT-KLH serum was 9.8 µg/kg. The recovery rate of CIT from spiked grain samples was between 81.6% and 132%. The cross-reactivities of the anti-CIT-KLH serum against salbutamol, ractopamine, patulin, and aflatoxin B1 were less than 1.0%. A total of 88 samples of corn and rice were collected from farms and supermarkets in northeastern China. Among the samples tested by IC-ELISA, CIT was not detected in 85 (96.6%) of the samples. Only 1 corn and 2 rice samples were positive for CIT. The risk of CIT in corn and rice from northeastern China seems to exist as a public health concern and CIT concentration should be continuously monitored.

Won Jong Lee is a professor in the Department of Food and Nutrition at Gangneung Wonju National University, Korea. He received his Ph.D. degree in cereal science from North Dakota State University.

45

Effect of increasing nitrogen fertilization on barley protein content and endosperm modification during malting

A. L. MACLEOD (1), M. S. Izydorczyk (1), J. T. O'Donovan (2)
(1) Canadian Grain Commission, Winnipeg, MB, Canada; (2) Agriculture and AgriFood Canada, Lacombe, AB, Canada

Only about 25% of barley is selected for malting in Western Canada annually due to strict quality specifications, including acceptable levels of grain protein. While application of nitrogen fertilization can increase yield, it can also impair quality by increasing protein to undesirable levels. Barley with high grain protein content is difficult to modify and limits the amount of potential extract. The objective of this study was to determine the responses of four relatively new malting barley cultivars (AAC Synergy, CDC Kindersley, Voyageur, and Cerveza) to increasing nitrogen rates compared to the response of AC Metcalfe, the most commonly grown malting cultivar in Western Canada. In the first year of this study, the five cultivars were grown at four rates of nitrogen fertilization (0, 25, 50, and 100 kg/ha), producing grain with a range of protein levels. While increasing rates of nitrogen fertilization generally resulted in increased grain protein levels and associated decreases in malt extract, not all varieties responded similarly. AAC Synergy and CDC Kindersley had lower levels of protein at higher nitrogen levels. This resulted in better endosperm modification as indicated by improved friability, lower wort β-glucan, and increased levels of soluble protein. Preliminary results suggest that varieties differ with respect to their ability to resist the negative effects of increasing rates of nitrogen, resulting in smaller reductions in friability and malt extract than the check cultivar, AC Metcalfe. This indicates that the need to restrict application of nitrogen fertilizer in order to achieve acceptable grain protein levels, which has a detrimental effect on yield, can be overcome with specific variety choices.

Aaron MacLeod joined the Canadian Grain Commission in 2005 and is currently a chemist in the Barley Research Unit of the Grain Research Laboratory. The unit provides quality assurance for malting barley grown in Western Canada and conducts research on factors affecting malting barley quality and quality measurement methods. Aaron holds a B.S. degree in chemistry from the University of Western Ontario. He has been a member of ASBC since 2008, has participated in collaborative studies of numerous methods, and is currently a member of the ASBC Technical Committee.

46

Components in black malt impacting beer foam

M. KANAUCHI (1), C. W. Bamforth (2)
(1) Miyagi University, Sendai Miyagi, Japan; (2) University of California, Davis, Davis, CA, U.S.A.

Myriad factors impact the stability of beer foam. Substances can be classified into two categories: foam-positive and foam-negative. It was originally proposed by Bishop that intense heating of malt leads to the production of materials that are especially foam-positive, perhaps due to the cross-linking of polypeptides and polysaccharides. Small scale mashing was carried out with roasted barley and black malt and the foaming properties of materials extracted in the wort investigated. Mashing in the presence of added amylase appears to have a significant impact on the foaming properties of extracts of roasted barley, although not black malt. Generally the foaming performance of extracts of black malt is superior to that from roasted barley, but not if amylases are included in the extraction of the latter. The paper will report studies on the isolation and characteristics of the foam-active materials from these preparations.

Makoto Kanauchi graduated from the Tokyo University of Agriculture in Tokyo, Japan, in 1996 and received a Ph.D. degree in bio-regulation control from that university in 1999. He worked in Charles Bamforth's Laboratory in the Department of Food Science and Technology, University of California at Davis, from 1999 to 2003. Subsequently, he was employed at the Institute of Food Science, Fuji Oil Co. Ltd., in Moriya, Ibaraki, Japan, as a researcher from 2003 to 2005. Since 2005, he has been at the Department of Food Management, Miyagi University.

47

Determination of wheat protein in beer using the wheat/gluten (gliadin) ELISA kit: 2014 BCOJ Collaborative Work

T. WATANABE (1), T. Akiba (2), R. Arai (3), Y. Ishizuka (4), M. Kanauchi (5), M. Kato (3), K. Kusaka (6), K. Kuwahara (7), T. Miyagi (8), S. Mori (9), A. Ohuchi (10), S. Tatsu (11)
(1) Sapporo Breweries Ltd., Yaizu, Japan; (2) Wakodo Co., Ltd., Tyofu, Japan; (3) Kirin Company, Ltd., Yokohama, Japan; (4) Suntory Beer, Ltd., Shimamoto, Japan; (5) Miyagi University, Sendai, Japan; (6) National Research Institute of Brewing, Higashihiroshima, Japan; (7) Morinaga Institute of Biological Science, Inc., Yokohama, Japan; (8) Orion Breweries, Ltd., Nago, Japan; (9) Pokka Sapporo Food & Beverage Ltd., Kitanagoya, Japan; (10) Asahi Breweries, Ltd., Moriya, Japan; (11) Suntory Global Innovation Center, Ltd., Shimamoto, Japan

Barley malt is the main ingredient in most Japanese beers, but wheat is also used as an ingredient in some types of beer. The objective was to establish a quantitative method for measuring allergenic wheat protein. The method will be able to detect contamination from a production line for beer containing wheat in beer not containing wheat produced on the same line. It will be useful to assess the impact on consumers who are allergic to the protein. The Consumer Affairs Agency in Japan indicates that the ELISA method is applicable to quantitate the allergenic wheat protein, and foods with wheat protein contents exceeding 10 μg/g are evaluated positively. The ELISA method has not been used with beer in Japan until now. The BCOJ subcommittee was charged with evaluating the ELISA method. We evaluated wheat protein contents in beer with FASPEK Wheat/Gluten (Gliadin) ELISA Kit II which met the guidelines determined by the Consumer Affairs Agency. The collaborative work was performed by 12 associates. The statistical summary of results were as follows: RSD_r ranged from 2.0 to 4.7%; RSD_R ranged from 7.5 to 20.1%. Recovery of wheat protein was 83.8%. We judged these results were acceptable. The subcommittee recommended that the FASPEK Wheat/Gluten (Gliadin) ELISA method be adopted for inclusion in the Methods of Analysis of BCOJ.

Takayuki Watanabe received a degree from the Department of Agricultural Chemistry, Hokkaido University, Japan. He began his career as a packaging engineer in 1991 at the Sendai brewery, Sapporo Breweries Ltd. He worked in Sendai, Saitama, and Kyushu as a packaging engineer for 12 years. He worked in the Osaka brewery as a brewer for 4 years. He began work as a chemist at the Frontier Laboratories of Value Creation in 2008. He joined the BCOJ Analysis Committee in 2012.

48

Chinese barley malt filterability related proteins explored by the proteomic strategy

X. LI (1), J. Sun (1), T. Zhou (1), Z. Jin (1), F. Gao (1), G. Cai (1), J. Lu (1)
(1) National Engineering Laboratory for Cereal Fermentation Technology, School of Biotechnology, Jiangnan University, Wuxi, China

The filterability defect of domestic barley malt is a long-term disturbing problem in the Chinese brewing industry. In contrast, beer manufacture using Canadian and Australian barley malts seldom encounters this problem. The direct factor impacting filterability historically was considered to be certain incomplete hydrolyzed macromolecules, such as β-glucan, arabinoxylan (AX), and prolamine, which was attributed to complex reasons, including low expression level or activity of endogenous hydrolases, differential expression of isozymes among barley cultivars, affections of enzyme regulators, and even the excessive contents of macromolecules in barley. To systematically characterize filterability related proteins in Chinese barley malt, a proteomic strategy as applied. The Canadian Metcalfe barley malt, which has superior filterability, and the Chinese Dan'er barley malt, which has filterability problems, were chosen for comparative proteomic by two-dimensional difference gel electrophoresis (2D-DIGE). The Dan'er and Metcalfe barleys contained similar amounts of macromolecules. While the contents of macromolecules in their Congress wort were significantly different, with 226.1 mg/L of β-glucan and 1,072 mg/L of AX in Dan'er wort, and 102 mg/L of β-glucan and 750.1 mg/L of AX in Metcalfe wort, respectively. The proteomic results showed that Metcalfe malt had more hydrolases such as β-amylase and arabinofuranohydrolase (AXAH-I), while Dan'er malt expressed higher levels of pathogen related proteins, especially the serpins and peroxidase (POD). At the same time, the activity of AXAH-I was monitored during the Congress mash, using Dan'er and Metcalfe malts. Throughout the mashing process, the AXAH-I activity of Dan'er malt was always lower than that of Metcalfe. The highest AXAH-I activity shown by Dan'er wort was 9 mU/g malt, which was only 60% of the activity of Metcalfe (13 mU/g malt). To verify its role in malt filterability, a certain amount of AXAH-I was purified from Dan'er malt and added to the start of the EBC mashing process. It was found that extra AXAH-I added to the mash enhanced the separation rate, decreased viscosity, and also, unexpectedly, increased turbidity. When 6 mU/g malt of AXAH-I was added, the separation rate and turbidity were increased by 34.2% and 32.5%, and viscosity was reduced by 5.5%. Meanwhile, the contents of macromolecules, including high molecular weight AX and β-glucan, were reduced. Dan'er malt was also found to contain more POD, which could promote the cross-link between AX and ferulaic acid (FA) to form feruloylarabinoxylans. The concentration of monomer AX-FA, the activity of POD, and the separation rate of 10 collected malt samples were detected in their Congress wort, the results showed that the wort separation rate was negatively correlated with these factors. With added ascorbic acid, the POD inhibitor to the EBC mashing process using Dan'er malt, the separation rate of Congress wort was significantly increased. The roles of other different proteins in filterability still need to be researched further.

Xiaomin Li is an associate professor at Jiangnan University. Her research focuses on the molecular genetics of yeast and quality control of raw materials for brewing, such as filterability, toxins, and PYF, etc.

49

Information to action: Using the ASBC Flavor Wheel to unwind the complexity of beer flavor

D. O. LETCHER (1), L. Guerdrum (2)
(1) Paha Hills Inc., Wheaton, IL, U.S.A.; (2) New Belgium, Fort Collins, CO, U.S.A.

The ASBC Sensory Subcommittee has recently produced an updated model for describing beer flavor that is scientifically aligned with the sensory research of the last three decades and accounts for new complexities in brewing science. Nevertheless, a two-dimensional model remains an insufficient format for making this information actionable; to address this problem, the new ASBC Flavor Wheel is being released in conjunction with the ASBC Flavor Wheel App. The Flavor Wheel App allows for the easy transmission of vital information like attribute origin, threshold level, and reference. For the first time, the entire picture can be accessed with the click of a button, giving the user the ability to use the flavor wheel as a multidimensional training and troubleshooting tool. The app displays a computer generated, graphic representation of the flavor wheel with links to the ASBC Beer and Hop Flavor Databases. By providing both graphic and text search functionality it allows users to dive deeper into beer flavor.

Drew Letcher is a software engineer with more than 25 years of experience in software development, specializing in web-based databases, search technology, and big data analytics. He and his son are opening a new brewery with a sensory analysis lab in Iowa.

50

Sensory bitterness quality of oxidized hop acids: Humulinones and hulupones

M. PELTZ (1), V. Algazzali (2), T. Shellhammer (1)
(1) Oregon State University, Corvallis, OR, U.S.A.; (2) John I. Haas, Yakima, WA, U.S.A.

Extracts of known oxidized hop acids, humulinone and hulupone, were prepared from α-acid and β-acid extracts using methods developed by Cook et al. (1955) and Wright (1963). High purity humulinone (93.7%) and hulupone (92.5%) extracts were achieved through reverse-phase preparative liquid chromatography and measured using high pressure liquid chromatography (HPLC-MS). Using results from prior sensory evaluation, the purified extracts along with commercially available iso-α-acids were dosed into unhopped lager beer at approximately equi-bitter concentrations (28 mg/L humulinone, 21 mg/L hulupone, 18 mg/L iso-α-acids). The dosed beers were evaluated by a panel of 10 trained tasters using descriptive analysis. The panel rated the quality of the bitterness using five descriptive terms: peak bitterness, duration, metallic, medicinal/harsh, and vegetative. The panel was capable of discriminating the beer treatments on four of the five sensory attributes, and the results suggest that the hulupone and iso-α-acid treatments were indistinguishable in bitterness quality, while the humulinone treatment was perceived to be lower in peak bitterness, less medicinal, and shorter in duration. Previous work in our lab has demonstrated that the bitterness intensity of humulinones and hulupones is greater than previously suspected. The presence of oxidized hop acids and differences in sensory bitterness quality should be taken into account when formulating beer with aged/oxidized hops.

Meghan Peltz is a second year master's degree student studying under Thomas Shellhammer at Oregon State University, specializing in the areas of sensory and hop chemistry. Additionally, she is an active member of the ASBC Sensory Subcommittee. Prior to pursuing a graduate degree Meghan

worked at Kalsec Inc. as a sensory scientist from 2009 to 2013. There she became interested in the study of hop chemistry and sensory after her specialization in Kalsec's hop extracts product line as a sensory panel leader, analyst, and technical sales representative. Meghan holds a graduate certificate in applied statistics from Penn State University World Campus and graduated with a B.S. degree in food science from Michigan State University.

52

Automating measurement of malt diastatic power

A. SUONIEMI-KÄHÄRÄ (1)
(1) Thermo Fisher, Vaanta, Finland

Malt diastatic power is determined by measuring a D-glucose end product with a specific enzymatic reaction. Instead of using traditional titration measurements or a flow analyzer for reducing sugars, a discrete analyzer is used. The advantage of such a technique is speed, ease-of-use, and the ability to test a broad range of analytes, like free amino nitrogen (FAN), sulfur dioxide (SO_2), bitterness, protein, or color. This method principle is based on photometric determination of diastatic power in homogenous liquid malt samples using an automated Thermo Scientific Gallery Plus Beermaster analyzer. The process extracts enzymes by malt infusion, followed by the reaction of a solution with ASBC Malt-6 special starch substrate under the controlled conditions of time, temperature, pH, and enzyme-substrate relations. The resulting sugars, primarily maltose, further react with α-glucosidase to produce glucose. Glucose is measured using the Thermo Scientific D-glucose kit, a method based on the reaction of glucose with hexokinase and glucose-6-phosphate dehydrogenase. Measurements are taken at 37°C with a 340 nm filter. Preparation of the special starch solution, malt infusion, calibrator, and α-glucosidase solution is required. The D-glucose method is based on ready-to-use traceable system reagents. After formation of the sugars, all reagent and sample additions, measurements, and reporting of results are automated. First results are reported quickly and several samples can be analyzed without the need for additional hands-on time. The sample preparation process described in the ASBC Malt-6 method can be used. Megazyme EMAST malt amylase was used as a calibration standard. The lot concentration is usually about 220 ASBC units and a linear calibration type can be used. If additional speed is required, the analyzer's software allows the enzyme calibration to be changed to a factor calibrated test and the factor can be verified by an automated request for a quality control sample. This method has been tested with samples varying from 52 to 368 ASBC units. A method correlation study compared gallery results to the reference method. Preliminary results were obtained using Sigma-Aldrich α-glucosidase which was diluted with 0.5 % NaCl. The method has been further developed by improving the solution of α-glucosidase. With a new citrate buffer, the α-glucosidase enzyme reagent can be frozen in aliquots enabling cost-effective enzymatic analysis. The discrete analyzer allows flexible, fast, and accurate diastatic power analysis, as well as simultaneous analysis of other analytes. By using the sample and substrate preparation methods already used by the laboratory along with an enzyme preparation as a calibrator, results can be easily correlated to existing methods.

Annu Suoniemi-Kähärä currently works as an R&D manager for Thermo Fisher Scientific and is focused on industrial systems and leading the team in developing beer analysis system methods, as well as other food and water chemistry tests for discrete analyzers. From 2004 to 2010 she served as a product line manager for industrial solutions and from 2002 to 2004 as a product manager for clinical discrete analyzers. From 2000 to 2002, she worked as an international product manager on luminometric products for Labsystems (currently part of Thermo Fisher Scientific). Prior to that she worked as a food research scientist at Valio Ltd. Annu received her Ph.D. degree in microbiology from the University of Helsinki in 1997, her licentiate degree in1995, and her master's degree in 1992.

53

Comparison of tetrad and triangle testing as an applicable discrimination test

A. DONELAN (1), M. Becher (1), A. Vaughn (2), A. Fritsch (2)
(1) The Boston Beer Company, Cincinnati, OH, U.S.A.; (2) The Boston Beer Company, Boston, MA, U.S.A.

Panelist availability is a primary struggle for many sensory programs. This creates challenges in obtaining statistically powerful results and can lead to improper conclusions. A triangle test is the most widely used difference test. However, it requires a large number of panelists to obtain results with confidence. The tetrad test is a new alternative method. In this study, we will compare not only the theory of tetrad versus triangle but the practical application as well. Panelists evaluated products using both tetrad and triangle tests with known differences in diacetyl. The results of this study indicate the tetrad test is more operationally powerful and applicable than the triangle test.

Amy Donelan received a B.S. degree in food science and technology from the University of Tennessee. She worked in the Kansas State University Sensory and Consumer Research Labs for 2 years before starting as a sensory technologist at the Samuel Adams brewery in Cincinnati, OH.

54

Determination of sugar metabolism profiles of non-traditional yeasts in the *Saccharomyces* and *Brettanomyces* families

J. D. Cook (1), W. A. DEUTSCHMAN (1)
(1) Westminster College, Salt Lake City, UT, U.S.A.

Maltotriose is a major constituent of brewing wort and is metabolized poorly by many strains of brewing yeast. The presence of residual extract in finished beer can have significant impacts on flavor, packaging stability, and resistance to spoilage bacteria. Recently the popularity of beers brewed or aged with non-traditional yeast strains, particularly in the *Brettanomyces* family, has risen dramatically. While the maltotriose fermentation profile of more traditional yeasts such as *Saccharomyces cerevisiae* and *S. pombe* is well known, the ability to metabolize maltotriose by yeasts in the *Brettanomyces* family is less well characterized. The objective in this study was to begin the process of determining the metabolic preferences and abilities of several non-traditional yeast strains such as *B. bruxellensus*, *B. custersianus*, and *S. ludwigii* in comparison to that of a commonly used strain of *S. cerevisiae*. Standard malt extract wort was prepared and inoculated with each yeast strain. The wort was aerated and fermentation was allowed to proceed to completion. The sugar profile of the fermentation mixture was monitored periodically using HPLC with an Aminex HPX-87H column and ELSD detection. We found that the ability to metabolize maltose and maltotriose varied widely between different yeast strains. Whereas *S. cerevisiae* is known to consume glucose, maltose, and maltotriose, we found that neither *B. custersianus* nor *S. ludwigii* were able to metabolize maltose, but were able to clear glucose and maltotriose efficiently from the media. This work suggests that final fermentation or aging of finished beer in the presence of these yeasts could be a useful tool to assure complete fermentation of maltotriose, increase package stability, and add protection against spoilage bacteria.

William Deutschman earned his Ph.D. degree in chemistry in 2001 at the Institute of Molecular Biology at the University of Oregon. From 2001 to 2006, he taught biochemistry at Plattsburgh State

University in Plattsburgh, NY. In 2006, he moved to Westminster College in Salt Lake City, where he currently teaches chemistry, biochemistry, and brewing science, while also pursuing research projects with undergraduate students in the areas of brewing and fermentation science.

56

Simultaneous quantification of furaneol and sotolon in beer and other alcoholic beverages by in-solution derivatization-GC-MS analysis

J. Zheng (1), F. Yuan (2), M. C. QIAN (2)
(1) Sichuan University and Oregon State University, Chengdu China and Corvallis, OR, U.S.A.; (2) Oregon State University, Corvallis, OR, U.S.A.

Furaneol and sotolon have been identified in beer, wines, and other alcoholic beverages as very important aroma compounds. However, it is difficult to reliably analyze these compounds due to their high polarity and thermal instability. In this study, a reliable and robust method was developed to analyze furaneol and sotolon based on *N,O*-bis(trimethylsilyl) trifluoroacetamide (BSTFA) silyation coupled with GC-MS. Various derivative parameters were evaluated, and the results demonstrated that the ratio of sample, BSTFA (5% trimethyl chlorosilane, TMCS), and dichloromethane of 1:1:1, derivatization temperature of 50°C, and reaction time of 30 min were the best for the reaction. Recovery of furaneol and sotolon was 92.5 and 85.2%, respectively. Limit of detection (LOD) and limit of quantification (LOQ) were 7.3 and 9.1 µg/L for furaneol and 24.3 to 30.4 µg/L for sotolon, respectively. The optimal method resulted in good repeatability and reproducibility with inter- and intra-day relative standard deviations less than 11%. The developed method was applied to wines, beer, and iced tea; the results showed that the beer samples had the highest furaneol and sotolon concentrations, ranging from 101 µg/L to 487 µg/L, which was 200–400 times higher than in Pinot Noir wine and 20–40 times higher than the iced tea.

Michael C. Qian is a professor of flavor chemistry at Oregon State University and chair of the Food and Agricultural Food Chemistry Division of the American Chemical Society (2014). He received his Ph.D. degree from the University of Minnesota under the guidance of Gary Reineccius. Michael's research interests at Oregon State University cover aroma/flavor chemical/biochemical generation in dairy products, small fruits (blackberries, raspberry, and strawberry), wine and wine grapes, beer, and hops. He has published many research papers, including 12 book chapters and 4 books in the field of flavor chemistry, and is a frequent speaker at national and international meetings. In 2014, Michael was named a Fellow of the Agricultural and Food Chemistry Division of the American Chemical Society.

57

A simple, cost-effective treatment for declumping super yeast

L. L. CHAN (1), A. Wilson (2), K. McCulley (1), B. Belete-Gilbert (1)
(1) Nexcelom Bioscience, Lawrence, MA, U.S.A.; (2) Brew Hub, Lakeland, FL, U.S.A.

In the early fermentation stages, many types of yeast cells may form clusters that can increase the difficulty for both manual counting, as well as automated image-based cell counting. In this work, we demonstrate a simple and cost-effect method for declumping yeast cells in order to facilitate accurate automated cell counting and viability measurement. We examined the Super San Diego Yeast that has high clumping characteristic during fermentation. A beer sample with Super Yeast was collected from the fermentation tank and treated with a small dose of HCl for 10–30 seconds. A control sample was treated with the same dose of H_2O for the same duration. Concentrations of both samples were then measured in an Cellometer X2 image cytometer. Results showed that after declumping treatment, the yeast concentration increased due to the single cell suspension that can be accurately counted. The declumping method also improved the accuracy of measuring viability with PI using Cellometer X2. By utilizing the declumping method, clumpy yeast or yeast in early stage of fermentation can be made into a single cell suspension, which can improve the accuracy in cell counting and viability.

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. 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).

58

Formation of humulinones in hops and hop pellets and its implication for dry-hopped beers

J. P. MAYE (1), R. J. Smith (2), R. J. Wilson (3)
(1) Hopsteiner, New York, NY, U.S.A.; (2) Hopsteiner, Yakima, WA, U.S.A.; (3) Hopsteiner, London, U.K.

Humulinones are formed by the oxidation of α-acids. Their detection in hops, hop pellets, and dry-hopped beers is relatively new. Humulinone formation in leaf hops and continued formation days following hop pelleting can occur in the absence of air. High HSI (hop storage index) hops have higher concentrations of humulinones than low HSI hops and concentrations as high as 0.2%–0.5% w/w are typically found in hops and hop pellets. Humulinones have been measured in dry-hopped beers at concentrations as high as 24 ppm and their bitterness has been reported to be 65% that of iso-α-acids. Detailed analysis of the concentration of humulinones found in hops, hop pellets, and dry-hopped beers will be presented.

John Paul Maye is the technical director at Hopsteiner. John Paul received his Ph.D. degree in organic chemistry from Purdue University in 1994. He started his work as a hop chemist in 1993 at Pfizer's Brewing Ingredients Division located in Milwaukee, WI. He has published several papers and patents on hops and their applications inside and outside of brewing. In 2000 he was the recipient of the Eric Kneen Memorial Award for his publication in the Journal of the American Society of Brewing Chemists *on the preparation of HPLC standards for isomerized and reduced α-acids. He is also a founding member and secretary of the International Hop Standards Committee.*

59

Characterization of *Humulus lupulus* microbial communities by Illumina 16S rRNA gene amplicon sequencing

S. J. BRITTON (1), M. E. Allen (2), A. J. Piefer (2), P. T. Benziger (2), J. M. Balnis (2)
(1) Duvel Moortgat USA, Cooperstown, NY, U.S.A.; (2) Hartwick College, Oneonta, NY, U.S.A.

The female inflorescence of the common hop (*Humulus lupulus*) is a necessary ingredient that provides distinctive aromatics, bitterness, and antiseptic properties to beer. Although substantial research has been conducted on the antiseptic properties of hops, almost no research exists on the natural microbial communities that populate this perennial herbaceous vine. High-throughput DNA sequencing was conducted on samples from hop plants to characterize the microbial community of cones and leaves, and

from the soils located at the base of mature plants. Samples were obtained aseptically from hops vines in September 2014 and stored at –80°C until DNA extraction. Microbial genomic DNA was extracted directly from each soil sample (n = 8), and the microorganisms removed from the surfaces of cone (n = 9) and leaf (n = 5) samples by sonication. The V3 and V4 regions of 16S rRNA genes were PCR amplified into single amplicons of approximately 460 bp, which were sequenced with an Illumina MiSeq. A genus-level hierarchical classification grouped samples into two distinct clusters, one representing the microbiomes of cones and leaves and the second the microbiomes of soils. Shannon diversity indexes for cone and leaf samples were mostly lower than for soil samples. Cone and leaf microbiomes were dominated numerically by the genera *Sphingomonas* (phylum Proteobacteria), *Calothrix* (phylum Cyanobacteria), and *Pseudomonas* (phylum Proteobacteria). In most samples these genera represented 50% or more of the sequences yet none of these appeared in soils. Soils also differed in that the most common genera rarely accounted for more than 20% of all sequences. The most common genera in soils included *Megasphaera* (phylum Firmicutes), *Pedosphaera* (phylum Verrucomicrobia), and three from the phylum Proteobacteria: *Azospirillum*, *Chondromyces*, and *Rhodoplanes*. At the conclusion of this study we elucidate the microbial communities associated with *H. lupulus*, a crop of significant importance to the brewing community, and reveal potential agents of contamination resulting from the post-boil addition of hops.

Scott J. Britton holds an M.S. degree and is the US Quality Group manager for Duvel Moortgat USA and adjunct instructor of biology at Utica College, Utica, NY. He completed his graduate work in biotechnology at Johns Hopkins University (Baltimore, MD).

60

Selective adsorption of hop derived aroma substances by nonviable dry brewing yeast

Y. NORO (1), A. Murakami (1), J. Furukawa (2), Y. Kawasaki (1), R. Ota (1)
(1) Kirin Brewery Company, Limited, Yokohama, Japan; (2) Kirin Brewery Company, Limited, Okayama, Japan

There have been many studies on selective adsorption of nonpolar substances by viable brewing yeast. Besides viable brewing yeast, we have found that nonviable dry brewing yeast also has the same characteristic. Viable brewing yeast adsorbs nonpolar substances selectively. Therefore, hop derived polar substances such as myrcene and humulene, resin-like aroma substances, are adsorbed to a greater extent compared to less polar substances such as linalool and geraniol, floral and/or fruity aroma substances. This is one of the reasons for favorable modification of hop aroma during beer fermentation. With this selectivity of viable brewing yeast, hop flavors have been developed by bringing viable brewing yeast into contact with hop oil. However, the method requires control of fermentation. Furthermore, alcohol is produced and as a result, it could not be used for non-alcohol beverage products, such as alcohol-free beers. Therefore, the objective of the study was to find a suitable, easy to handle and non-alcohol producing adsorbent which is a substitute for viable brewing yeast. In a first experiment, activated carbon and synthesized adsorbent were added to hop oil respectively. Both results showed no selectivity in adsorption. Not only myrcene and humulene, but also linalool and geraniol were more than 90% adsorbed. In the second experiment, non-viable dried brewing yeast was put into contact with hop oil. The yeast is a by-product of beer and is produced by drying yeast from beer at a temperature higher than 100°C. Because of its high content of nutrients, such as amino acids and minerals, it is used in cattle feed or dietary supplement for humans or lipid membranes of the yeast are used as materials for medical capsules. Recent studies revealed its function as biosorbent. For example, it adsorbs iron ions, odor inducing factors, from red wine or cadmium ions from wastewater to prevent water pollution. Therefore, we have investigated its selectivity of adsorption to hop derived resin-like aroma substances. The result of the experiment showed a selectivity similar to viable brewing yeast. Myrcene and humulene were adsorbed at 90% and 85%, respectively. On the other hand, adsorption of linalool was 20% and of geraniol was 35%. No alcohol was produced. Therefore, we have identified nonviable dry brewing yeast as a suitable biosorbent for producing hop flavors.

Yoko Noro worked for Kirin Brewery Company Limited after receiving a master's degree in agricultural science from Kyoto University in 2009. She worked in the Brewing Department of the Sendai brewery for 3 years as an assistant manager and then entered the Brewing Technology Development Center, where she conducted research on hop aroma. Since 2013, owing to reorganization, she has been working for the Research and Development Division in Kirin Brewery Company, Limited, with the same hop theme.

61

Examination of extraction solvents to improve laboratory efficiency and reduce solvent use for the analysis of hop products

P. S. Jensen (1), C. ERMEY (1), S. W. Garden (1)
(1) John I. Haas, Inc., Yakima, WA, U.S.A.

Hops are typically analyzed for their bitter acids composition through the use of ultraviolet (UV) spectrophotometric or high performance liquid chromatography (HPLC) analysis. American Society of Brewing Chemists (ASBC) methods have been developed for UV spectrophotometric and HPLC analysis of CO_2 hop extracts (Hops-8 and Hops-14, respectively). Hops-14 can also be used for HPLC analysis of hop cones and pellets, but a separate method has been approved for UV spectrophotometric analysis (Hops-6a). Each of the three ASBC methods (Hops-6a, 8, and 14) utilizes a different solvent protocol for extracting hop components for instrumental analysis. If the same solvent could be used to prepare samples for both UV spectrophotometric and HPLC analysis, it would reduce sample preparation time and laboratory solvent use significantly. Methanol is a solvent commonly employed in the extraction of hop components for analysis. In this study we explored the use of a common methanol solvent protocol for the preparation of cone hops, hop pellets, and CO_2 hop extract samples for UV spectrophotometric and HPLC analysis of their bitter hop acid components. A single solvent system utilizing methanol was found to produce statistically comparable results for UV spectrophotometric and HPLC analyses of CO_2 hop extracts. However, a methanol solvent system was not appropriate for extracting hop cones and pellets for UV spectrophotometric and HPLC analysis as the results were significantly different from analysis performed using the standard ASBC solvent protocols.

Cheryl Ermey earned her bachelor's degree in biology, with a minor in chemistry, in 2005 from Central Washington University in Ellensburg, WA. Since graduation she has worked in chemistry laboratories and has lots of experience in instrumental analysis. She has been working for John I. Haas in their Hop Quality Assurance Lab since her employment in 2008. Prior to working at Haas, Cheryl worked as a microbiology technician for Ag Health Labs in Sunnyside, WA, and as a chemistry technician for Batelle Toxicology Northwest in Richland, WA. Cheryl also spent 5 years as a volunteer firefighter with the West Valley Fire Department in Yakima County.

62

A comparison of quality: Freeze-dried versus kiln-dried Cascade hops

V. ALGAZZALI (1), M. Hodel (1), S. Garden (1)
(1) John I. Haas, Yakima, WA, U.S.A.

This study investigates freeze-drying hops (*Humulus lupulus*) and its effects on hop and beer quality. Cascade hops grown in Yakima, WA, were harvested from a single plot and then both freeze-dried and kiln-dried. A 5 kg proportion of the Cascade hops was freeze-dried at Oregon State University, and the remaining Cascades hops were conventionally dried in a commercial kiln. Instrumental analysis showed the freeze-dried hops contained substantially more oil than the kiln-dried hops (2.5 mL per 100 g vs. 1.6 mL per 100 g) and had a lower HSI than the kiln-dried hops (0.26 vs. 0.33). GC analysis of the hop cones indicated that the freeze-dried and kiln-dried Cascades also had differences in hop oil composition. Sensory analysis was carried out in beer to determine the flavor impact of the hop drying methods. A single malt lager was prepared as the control beer, bittered with high α extract to 20 BU. Forty liters of the lager was dry hopped with the freeze-dried Cascade hops and another forty liters was dry hopped with the kiln-dried Cascades hops; both at a level of 5.7 g per L (1.5 lb per bbl). A 14 member trained panel was capable of distinguishing the beers in triangle testing ($P = 0.01$, $N = 14$). In descriptive analysis testing, the panel scored the freeze-dried beer higher in grassy and earthy attributes, and the kiln-dried beer higher in fruity attributes. The drying method of the hops significantly impacted the aroma profile of the dry-hopped beers. Although the kiln-drying method produced hops with lower oil content and higher HSI, desirable flavor characteristics of the hops were transferred to the finished beer.

Victor Algazzali is a research and development scientist with John I. Haas in Yakima, WA. Victor joined John I. Haas in July 2014 and has focused his efforts on sensory analysis of hops and beer, hop product development, and instrumental analysis. Prior to joining John I. Haas, Victor earned his M.S. degree in food science at Oregon State University, working in Thomas Shellhammer's lab. Victor is a hop and beer enthusiast who particularly enjoys the many attributes of a well-hopped stout.

63

Sensory and analytical assessment of advanced hop products and the influence of hop starting material on bitterness

B. BUFFIN (1), T. Shellhammer (2), V. Algazzali (3), N. Bird (1)
(1) Kalsec Inc., Kalamazoo, MI, U.S.A.; (2) Oregon State University, Corvallis, OR, U.S.A.; (3) John I. Haas, Yakima, WA, U.S.A.

The use by brewers of pre-isomerized and reduced advanced hop products, such as dihydro-(r)-iso-α acids (Rho), tetrahydro-iso-α acids (Tetra), and hexahydro-iso-α acids (Hexa), continues to increase. Given the potential for each of these to impart different relative bitterness to beer, as well as the previously unexplored variance associated with the starting material and the manufacturing process involved, a study was undertaken to better assess how various hop acid products impact beer flavor and bitterness. Reduced hop acid products and starting materials evaluated included α-acid derived, β-acid derived, and iso-α-acid derived Tetra; α-acid and β-acid derived Hexa; and α-acid and iso-α-acid derived Rho. Each of the eight different reduced iso-α-acid products was individually dosed into unhopped lager beer and evaluated using two different trained sensory panels. The samples were rated on eight attributes: citrus, paper, medicinal, astringent, vegetative, metallic, peak bitterness intensity, and duration of bitterness. Through replicated descriptive analysis testing, the panels found significant differences between the different classes of advanced hop acids. For example, univariate and multivariate analyses of the descriptive data suggest that large differences exist between Rho, Hexa, and Tetra in lager beer while only subtle differences exist within the Tetra treatments. Surprisingly, the Tetra samples that exhibited the greatest differences in sensory scores were the most similar in terms of analog composition, suggesting that the relative concentrations of individual analogs (e.g., *co*-tetrahydro-iso-α acids) are not a valid predictor of sensory bitterness quality. Replicated triangle testing also found no differences within Hexa nor within Tetra treatments. While solubility and other physical differences can exist, generating Tetra from hop α-acids, iso-α-acids, or β-acids will produce a product of similar bitterness quality. Details of the product syntheses, brewing and dosing, analytical analysis, sensory analysis, and data processing will be discussed.

Brian Buffin is the director of corporate discovery, analysis, and quality for Kalsec, Inc., a leader in the supply of advanced hop products to the brewing industry. Brian holds Ph.D. and M.S. degrees in organometallic chemistry from the University of Utah and a B.S. degree in chemistry from Calvin College. After working in the diatomaceous earth industry for World Minerals/Celite, he spent more than 13 years in professorships at academic institutions before joining Kalsec in 2008. Brian has been active in the area of hops research for more than 7 years.

65

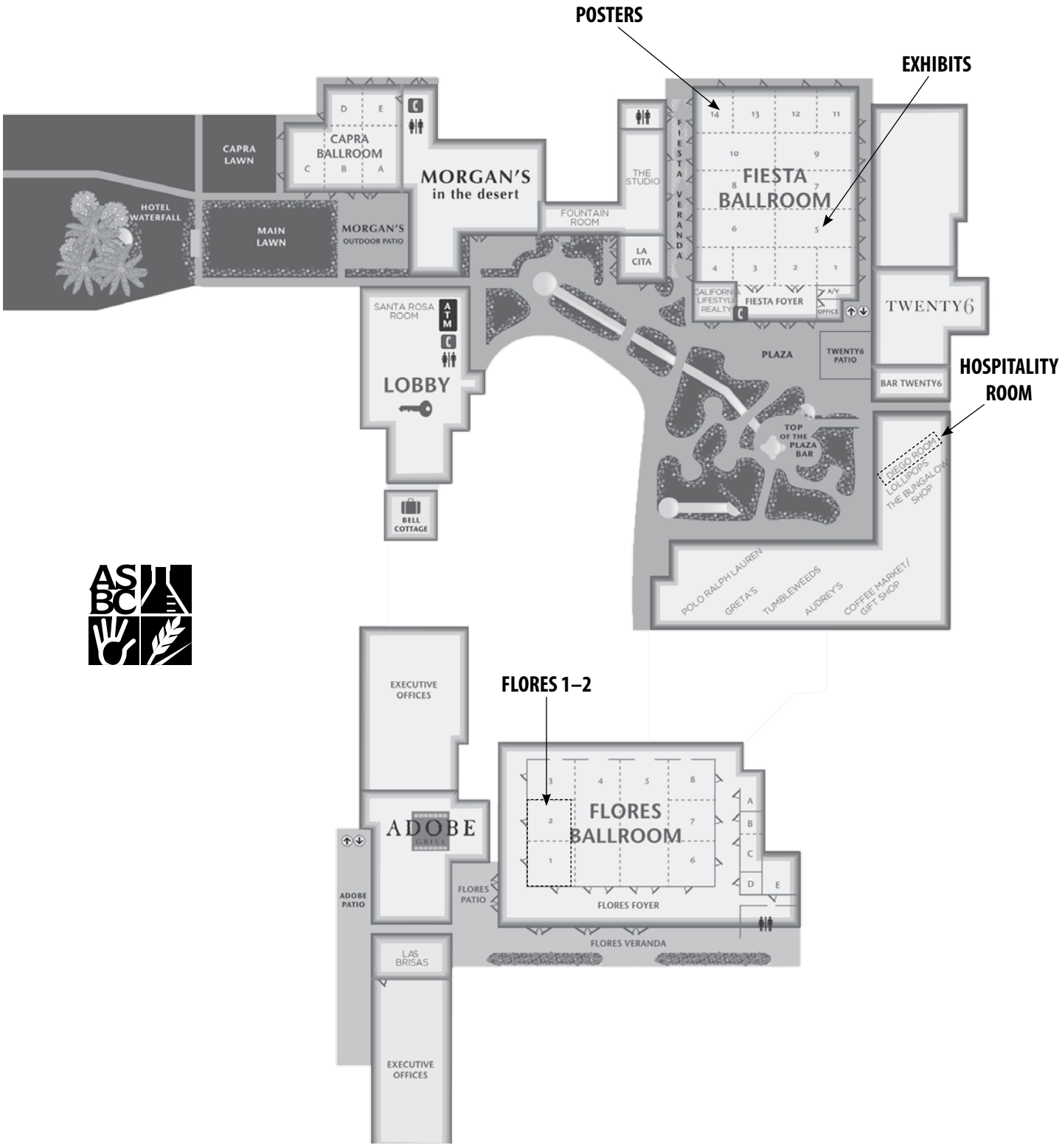
Validation and application of osmolyte concentration as an indicator to evaluate fermentability of wort and malt

S. HU (1), W. Fan (1), J. Dong (1), H. Yin (1), J. Yu (1), S. Huang (1), S. Huang (1), J. Liu (1)
(1) State Key Laboratory of Biological Fermentation Engineering of Beer, Tsingtao Brewery Co. Ltd., Qingdao, China

Prediction of brewing performance is important and most breweries still resort to a small-scale fermentability test, which entails the fermentation of wort under controlled conditions in an excess amount of yeast. The objective of study was to develop a new simple and quick approach based on osmolyte concentration (OC) to predict wort fermentability. Eight malts from seven barley cultivars were assayed for DP (diastatic power), starch-degrading enzymes (α-amylase, β-amylase, and limit dextrinase). Then malts were mashed to determine wort OC (WOC), RDF (real degree of fermentation), and sugar in a small-scale mashing protocol with a mash temperature of 65°C. First, WOC correlated better with α-amylase and limit dextrinase ($r = 0.881$ and 0.831, respectively; $P < 0.01$) than did DP, which only had a correlation with β-amylase ($r = 0.855$, $P < 0.01$). Moreover, wort RDF correlated significantly with WOC ($r = 0.929$, respectively; $P < 0.01$), suggesting that WOC can be used to evaluate malt fermentability without use of yeast and fermentation step. Meanwhile, WOC correlated dramatically with maltose, glucose, total sugars and fermentable sugars ($r = 0.923$, 0.928, 0.807, and 0.982, respectively; $P < 0.01$). These suggested that WOC can be used to quickly predict the wort sugar contents. Furthermore, the effect of mashing temperature and duration on the WOC, RDF, and sugar was discussed. Adjusted mash temperature near 65°C or extended mash duration dramatically increased RDF and WOC simultaneously, whereas ME (malt extract) was relatively stable. Similarly, WOC had significant correlations with RDF and fermentable sugars ($r = 0.912$ and 0.942, respectively; $P < 0.01$), suggesting that WOC could provide a simple and fast tool to assist brewers in optimizing mash parameters toward the production of ideal wort fermentability and sugar content. In conclusion, the ability of WOC to predict malt fermentability and sugar content allows brewers to keep better control of fermentability in the face of variation in malt quality and quickly adjust mashing conditions for the consistency of wort fermentability.

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

FACILITIES MAP



POSTERS

Poster Hours

Posters will be open all day on Monday and Tuesday in Fiesta 13–14, located adjacent to the exhibit and lunch area. Times are subject to change.

Sunday, June 14	11:00 a.m.–3:00 p.m.	Poster Set-Up
	4:00–6:00 p.m.	Exhibits and Posters Opening: "The Buzz" Happy Hour
Monday, June 15	12:00–2:00 p.m.	Exhibits, Posters, and Lunch *12:30–1:00 p.m. Odd-numbered poster authors at poster* *1:00–1:30 p.m. Even-numbered poster authors at poster*
Tuesday, June 16	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

Moderators: Kimberly Bacigalupo, Sierra Nevada Brewing Co.; Christine Hansen, E. & J. Gallo Winery; Dan Vollmer, Oregon State University

Poster Topics

40. M. Postulkova. Origin of hydrophobins and the constant "k" in Henry's Law govern the volume of foam formed by primary gushing of beer
41. S. Huang. Optimization of kilning conditions for multiparameter equilibrium of malt using response surface methodology
42. K. Inomoto. Establishing a new quantitative method for *Fusarium* hydrophobins using LC/MS/MS
43. J. Yu. Identifying the protein molecular weight distribution of different malting barley varieties by capillary gel electrophoresis
44. W. J. Lee. Development of a detection method and occurrence of citrinin in corn and rice from China
45. A. I. MacLeod. Effect of increasing nitrogen fertilization on barley protein content and endosperm modification during malting
46. M. Kanauchi. Components in black malt impacting beer foam
47. T. Watanabe. Determination of wheat protein in beer using the wheat/gluten (gliadin) ELISA kit: 2014 BCOJ Collaborative Work
48. X. Li. Chinese barley malt filterability related proteins explored by the proteomic strategy
49. D. O. Letcher. Information to action: Using the ASBC Flavor Wheel to unwind the complexity of beer flavor
50. M. Peltz. Sensory bitterness quality of oxidized hop acids: Humulinones and hulupones
52. A. Suoniemi-Kähärä. Automating measurement of malt diastatic power
53. A. Donelan. Comparison of tetrad and triangle testing as an applicable discrimination test
54. W. A. Deutschman. Determination of sugar metabolism profiles of non-traditional yeasts in the *Saccharomyces* and *Brettanomyces* families
56. M. C. Qian. Simultaneous quantification of furaneol and sotolon in beer and other alcoholic beverages by in-solution derivatization-GC-MS analysis
57. L. L. Chan. A simple, cost-effective treatment for declumping super yeast
58. J. P. Maye. Formation of humulinones in hops and hop pellets and its implication for dry-hopped beers
59. S. J. Britton. Characterization of *Humulus lupulus* microbial communities by Illumina 16S rRNA gene amplicon sequencing
60. Y. Noro. Selective adsorption of hop derived aroma substances by nonviable dry brewing yeast
61. C. Ermey. Examination of extraction solvents to improve laboratory efficiency and reduce solvent use for the analysis of hop products
62. V. Algazzali. A comparison of quality: Freeze-dried versus kiln-dried Cascade hops
63. B. Buffin. Sensory and analytical assessment of advanced hop products and the influence of hop starting material on bitterness
65. S. Hu. Validation and application of osmolyte concentration as an indicator to evaluate fermentability of wort and malt

EXHIBITION

Thank you to all 2015 exhibitors for being part of the meeting!

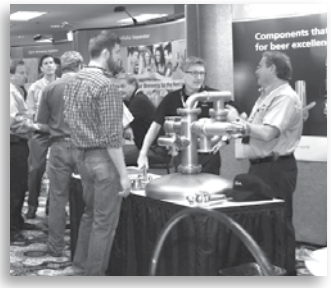


Exhibit Hall Hours

Location: Fiesta 1,2,5,7,9,11,12

Sunday, June 14	11:00 a.m.–3:00 p.m.	Exhibit Set-up
	4:00–6:00 p.m.	Exhibits Open: "The Buzz" Happy Hour
Monday, June 15	12:00–2:00 p.m.	Lunch and Exhibits
Tuesday, June 16	11:30 a.m.–1:30 p.m.	Lunch and Exhibits
	1:30–4:00 p.m.	Exhibit Take-down

Numerical Exhibitor Listing

Booth	Company
1	University of Nottingham
2	Roche Life Science
3	ERA, A Waters Company
4	Argelith Ceramic Tiles, Inc.
5	Cargill Malt
6	Anton Paar USA
7	Bruker BioSpin Corp.
8	Rheonix Food and Beverage Testing
9	White Labs
10	Hygiena
11	DSM Food Specialties
14	PerkinElmer
15	Invisible Sentinel
16	GEA Westfalia Separator
17	LECO
18	Logos Biosystems, Inc.
19	Hach
22	Thermo Scientific
23	Skalar
24	optek-Danulat, Inc.
25	Pentair
26	Aber Instruments Ltd.
27	BMT USA, LLC
28	Pall Corporation
29	Ecolab
30	Ellutia Inc.
31	Siebel Institute & Lallemand Brewing
32	American Tartaric Products, Inc.
33	Profamo Inc.
34	Gusmer Enterprises
35	Nexcelom Bioscience

EXHIBITOR DESCRIPTIONS

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

26 **Aber Instruments Ltd.,** 5 Science Park, Aberystwyth, SY23 3AH United Kingdom; Telephone: +44 (0)1970 636300, Web: www.aberinstruments.com, E-mail: sales@aberinstruments.com. Visit ABER to see and learn more about our PERFECTPITCH Skid for yeast pitching and our Countstar instrument for measuring yeast cell concentration and viability using image analysis. We will also be on hand to discuss our complete range of brewing instruments including our widely adopted COMPACT yeast monitor system.

32 * **American Tartaric Products, Inc.**, 1865 Palmer Ave., Larchmont, NY, 10538 U.S.A.; Telephone: +1.914.834.1881, Fax: +1.914.834.4611, Web: www.americantartaric.com, E-mail: atpbeer@americantartaric.com. ATP is proud to present a range of products that includes brewing process aids, antifoams, beer glasses, cleaning chemicals, clarifiers, DE, enzymes, filtration aids, stabilizers, filter sheets, cartridges, filters, keg lines/washers, pasteurizers, packaging equipment, and analytical equipment. ATP represents well-respected and established companies such as Alfatek, Eaton/Begerow, Birko Corp, E-P Minerals, Ashland/ISP, Lambrechts, Padovan, Stölzle, WeissBioTech, and others.

6 **Anton Paar USA,** 10215 Timber Ridge Dr., Ashland, VA, 23005 U.S.A.; Telephone: +1.804.550.1051, Fax: +1.804.550.1057, Web: www.anton-paar.com, E-mail: info.us@anton-paar.com, Facebook: www.facebook.com/AntonPaarUSA, Twitter: www.twitter.com/WhatsAPNews. Anton Paar is a leading supplier of instrumentation for key analytical parameters within the global brewing industry. With renowned laboratory instruments and process systems, the standard has been set for beer and wort gravity, alcohol, extract, DO/TPO, CO_2, haze measurements, and derived parameters.

4 **Argelith Ceramic Tiles, Inc.,** 103 N 11th Avenue, Suite 204, St. Charles, IL, 60174 U.S.A.; Telephone: +1.630.444.0665, Alt. Telephone: +1.630.746.9668, Fax: +1.630.444.0667, Web: www.argelithus.com, E-mail: info@argelithus.com. Argelith Ceramic Tiles is an industry leader in the manufacturing of industrial ceramic tiles. Our floors are used by several of the top five breweries in the world, as well as the top 10 U.S. craft breweries.

27 **BMT USA, LLC,** 14532 169th Dr. SE, Ste. 142, Monroe, WA, 98292 U.S.A.; Telephone: +1.360.863.2252, Web: www.bmtus.com, E-mail: sales@bmtus.com. BMT USA is the premier supplier of fully sanitary clean steam generators to the craft brewing industry. Utilized for the sterilization of kegs and bottles, BMT clean steam generators are manufactured in the United States utilizing all non-proprietary components. BMT also manufactures stability chambers and autoclaves.

7 * **Bruker BioSpin Corporation,** 15 Fortune Drive, Billerica, MA 01821; Telephone: +1.978.667.9580, Web: www.bruker.com. Bruker BioSpin Corporation manufactures EPR spectrometers for use in flavor-stability applications. Bruker's e-scan bench-top EPR spectrometer has been optimized for measuring and predicting oxidative flavor stability throughout the entire brewing process. With over 10 years in the field, Bruker EPR remains the gold standard for maximizing the shelf life of your beer.

5 * **Cargill Malt,** 15407 McGinty Rd. W, 135, Wayzata, MN, 55391 U.S.A.; Telephone: +1.952.742.0117, Web: www.cargillmalt.com. Whether you want to enhance existing product range or launch new on-trend beers, we have the ingredients and knowhow to help you thrive. As an international producer and marketer to the brewing industry, we help brewers succeed. We are committed to sharing our global knowledge and experience to help you reach your goals.

11 **DSM Food Specialties,** 3502 N Olive Road, South Bend, IN, 46628 U.S.A.; Telephone: +1 574.210.9979, Web: www.brewersclarex.com. DSM Food Specialties is a global supplier of differentiating food ingredients. We offer a range of brewing enzymes and support from our global team of brewmasters to ensure you gain maximum control over your production processes, improve your brewing efficiency, and deliver consistently clear, higher quality beer at a lower cost.

29 * **Ecolab,** 370 Wabasha Street North, St. Paul, MN, 55102 U.S.A.; Telephone: +1.651.293.2233, Fax: +1.651.250.2260, Web: www.ecolab.com. Ecolab is the global leader in water, hygiene and energy technologies and services, protecting people, and vital resources. Ecolab delivers comprehensive solutions and on-site service to help ensure safe food, maintain clean environments, optimize water and energy use, and improve operational efficiencies for customers in the food and beverage industries.

30 * **Ellutia Inc.,** 660 Riverland Dr., Suites D, Charleston, SC, 29412 U.S.A.; Telephone: +1.843.259.2307, Web: www.ellutia.com, E-mail: info@ellutia.com. Ellutia designs and manufactures a range of gas chromatography instruments and accessories. Ellutia offers a range of solutions for many of the different types of analysis required in the brewing and malting industries, including many ASBC methods.

3 * **ERA, A Waters Company,** 16341 Table Mountain Parkway, Golden, CO, 80403 U.S.A.; Telephone: 1.800.372.0122, Web: www.eraqc.com, E-mail: info@eraqc.com. Founded in 1977, ERA is the premier provider of Certified Reference Materials (CRMs) and Proficiency Testing (PT) products serving thousands of laboratories across multiple industries in more than 80 countries worldwide.

16 **GEA Westfalia Separator,** 100 Fairway Court, Northvale, NJ, 07647 U.S.A.; Telephone: +1.201.767.3900, Web: www.gea.com, E-mail: info.wsus@gea.com. GEA Westfalia Separator offers a full range of products in the dynamic filtration and separation categories, including high performance separators, clarifiers, decanters, and membrane filtration systems. Our decanters and disc machines are used in the beverage industry to separate liquids from solids and maximize yields.

34 * **Gusmer Enterprises,** 1165 Globe Ave., Mountainside, NJ, 07092 U.S.A.; Telephone: +1.908.301.1811, Fax: +1.908.301.1812, Web: www.gusmerenterprises.com, E-mail: sales@gusmerenterprises.com, Facebook: Gusmer Enterprises, 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.

19 * **Hach,** 5600 Lindbergh Drive, Loveland, CO, 80538 U.S.A.; Telephone: +1.970.663.1377, Alt. Telephone: +1.970.669.2932, Web: www.hach.com, E-mail: quotes@hach.com, Facebook: www.facebook.com/HachCompany, Twitter: @HachCompany. Hach has been helping the brewing industry for over 60 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 brewer, flavor stability and shelf life are critical to your brand and your overall business.

10 * **Hygiena,** 941 Avenida Acaso, Camarillo, CA, 93012 U.S.A.; Telephone: 1.888.494.4362, Alt. Telephone: +1.805.388.8007, Web: www.hygiena.com, E-mail: info@hygiena.com, Twitter: www.twitter.com/HygienaUSA. Recognized worldwide for accuracy, ease of use, and affordability, Hygiena's sanitation monitoring products are used extensively throughout the food and beverage industries to validate sanitation protocols and determine whether equipment is truly clean. The EnSURE Monitoring System measures ATP from surface and liquid samples. Free trials are available!

15 **Invisible Sentinel,** 3711 Market St, Suite 910, Philadelphia, PA, 19104 U.S.A.; Telephone: +1.215.966.6118, Fax: +1.215.921.5091, Web: www.invisiblesentinel.com, E-mail: info@invisiblesentinel.com, Facebook: www.facebook.com/InvisibleSentinel, Twitter: @Invisible_Sntl. Developed in conjunction with Victory Brewing Company, Veriflow brewPAL is the first product that provides same-day detection for the presence of *Pediococcus* and *Lactobacillus* species throughout the brewing process. This novel technology provides onsite detection and quantification of these microbes and reduces time-to-results from several days to less than three hours. Timely detection using Veriflow brewPAL can prevent spoilage, preserve integrity, and transform brewing quality control processes from reactive to preventive. The assay requires no enrichment or DNA purification steps, making it accessible to users with or without a microbiology background. The test can also test at any stage during production, not just finished beer. Compared with other molecular technologies on the market, the equipment associated with brewPAL is very capital efficient and is being adapted to test for other troublesome microbes that affect breweries as well.

17 **LECO,** 3000 Lakeview Avenue, St Joseph, MI, 49085 U.S.A.; Telephone: +1.269.985.5496, Alt. Telephone: 1.800.292.6141, Fax: +1.269.982.8987, Web: www.leco.com, E-mail: mary_jo_covert@leco.com. Since 1936, scientists have trusted LECO to deliver technologically advanced products and solutions for analytical science. Today's technologies for separation science resolve complex samples and pioneer high-sample throughput using GCxGC, GCxGC-TOFMS, and GC-TOFMS. A unique combination of easy-to-use software and advanced instrumentation provide innovative solutions for the most demanding applications.

18 * **Logos Biosystems, Inc.,** Doosan Venture Digm Suite 930, 415 Heungan-daero, Dongan-gu, Anyang-si, Gyeonggi-do, 431-755, South Korea; Telephone: +82.31.478.4185, Fax: +82.31.478.4184, Web: www.logosbio.com, E-mail: info@logosbio.com, Facebook: www.facebook.com/logosbiosystems, Twitter: Logos_Bio. Logos Biosystems is dedicated to the development and commercialization of innovative technologies to support the life science research community. Since 2008, Logos Biosystems has been developing a series of automated systems and imaging instruments for laboratories engaging in research with a cellular and molecular emphasis.

35 **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, E-mail: info@nexcelom.com, Facebook: www.facebook.com/nexcelom, Twitter: www.twitter.com/nexcelom. Nexcelom's Cellometer line of simple-to-use cell counters automates manual cell counting procedures by obtaining accurate counts, viability, and cell sizes in less than 30 seconds and only 20uL of sample. Fluorescence detection capabilities enable fast and simple determination of GFP transfection rates, PI-viability, and direct counting of WBCs without lysing.

24 * **optek-Danulat, Inc.,** N118W18748 Bunsen Dr., Germantown, WI, 53022 U.S.A; Telephone: 1.888.837.4288, Web: www.optek.com, E-mail: brew@optek.com, Twitter: www.twitter.com/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.

28 * **Pall Corporation,** 25 Harbor Park Dr., Port Washington, NY, 11050 U.S.A.; Telephone: 1.866.905.7255, Web: www.pall.com/foodandbeverage. Pall Food and Beverage provides products and services to ensure product quality and maintain process reliability in beverage and food production. Our solutions also assist in consumer protection, the reduction of operating costs and waste minimization.

25 * **Pentair,** 293 Wright St., Delavan, WI, 53115 U.S.A.; Telephone: +1.292.725.9026, Web: www.haffmans.nl, E-mail: hnasales@pentair.com. Pentair's brands include: Haffmans' quality control equipment for measuring carbon dioxide, oxygen, air, alcohol/extract, foam and turbidity, as well as carbon dioxide recovery; Südmo and Keystone Sanitary's stainless steel single seat, mix proof, butterfly, and specialty valves and components; and Beverage Filtration Solutions' Beer Membrane Filtration.

14 **PerkinElmer,** 710 Bridgeport Avenue, Shelton, CT, 06484-4794 U.S.A.; Telephone: 1.800.762.4000, Alt. Telephone: +1.203.925.4600, Fax: +1.203.944.4904, Web: www.perkinelmer.com, E-mail: customercareUS@perkinelmer.com. PerkinElmer, Inc., is a global leader focused on improving the health and safety of people and their environment. With our analytical instrumentation and leading laboratory services, we focus on improving the integrity and safety of the world we live in.

33 * **Profamo Inc.,** 26329 Basswood Ave., Rancho Palos Verdes, CA, 90275 U.S.A.; Telephone: +1.941.284.7990, Web: www.profamo.com. Profamo will have on their booth amongst others the Rotech Keg Monitoring system (it tells you everything you need to know about the cleaning, sterilization, and filling of your kegs) and Sigrist turbidity measurement equipment (very accurately and quickly measures turbidity no matter how dark or turbid the liquid).

8 **Rheonix Food and Beverage Testing,** 10 Brown Road, Ithaca, NY, 14850 U.S.A.; Telephone: +1.607.257.1242, E-mail: gmouchka@rheonix.com. Rheonix Food and Beverage Testing is announcing a subscription-based microbial testing service available to brewers. Brewers simply send samples overnight and PCR-based test results are returned electronically one day after receipt. The introductory test screens for lactic acid bacteria (*Lactobacillus* and *Pediococcus* spp.) and provides novel hop resistance information.

2 **Roche Life Science,** 9115 Hague Rd., Indianapolis, IN, 46250 U.S.A.; Telephone: +1.317.521.2000, Web: www.lifescience.roche.com. Roche's portfolio of LightCycler Real-Time PCR instruments combines the perfect combination of accuracy and flexibility, delivering a foundation for precise beer quality control testing. With sample throughput options at 32-, 96-, 384-well, and a host of probe/dye choices, you can truly choose the platform that best fits your needs.

31 * **Siebel Institute and Lallemand Brewing,** 900 N. North Branch St., 2: Suite 1N, Chicago, IL, 60642 U.S.A.; Telephone: +1.312.255.0705, Fax: +1.312.255.1312, E-mail: klemcke@siebelinstitute.com. The Siebel Institute of Technology offers more brewing-related courses than any other school. Our campus-based and web-based programs cover the full range of brewing-related subjects, offering world-class training that ranges from the fundamentals of brewing to advanced-level programs. We also offer onsite training, consulting, yeast management and production, lab services, laboratory media, and Lallemand yeast and nutrient products.

23 **Skalar,** 5012 Bristol Industrial Way, #107, Buford, GA, 30518 U.S.A.; Telephone: 1.800.782.4994, Fax: +1.770.416.6718, Web: www.skalar.com. The Skalar Beer/Wort/Malt Analyzer offers full automation of various industry parameters such as bitterness, ß-glucan, total sulfur dioxide, free amino nitrogen, ß-glucanase, soluble protein, diastatic power, and αamylase. The result is higher sample throughput with reduced analysis time. All methods follow worldwide guidelines such as ASBC, EBC, and Mebak to ensure accurate and laboratory comparable results without the use of expensive proprietary chemicals or correction factors.

22 * **Thermo Scientific,** 1214 Oakmead Parkway, Bldg. 10, Sunnyvale, CA, 94085 U.S.A.; Telephone: +1.408.481.4305, Web: www.thermoscientific.com/en/product/gallery-plus-automated-photometric-analyzer.html, E-mail: leala.thomas@thermofisher.com. Thermo Scientific Gallery series discrete analyzers use colorimetric, enzymatic, and electrochemical methods for analysis and quality control in the food and beverage industry. With automation, simultaneous determination of several analytes from a single sample is possible with first results available in as little as ten minutes.

1 **University of Nottingham,** International Centre for Brewing Science, Bioenergy & Brewing Science Building, Sutton Bonington Campus, Loughborough, Leicestershire, LE12 5RD United Kingdom; Telephone: +44 11595 16610, Web: www.nottingham.ac.uk/brewingscience/index.aspx, E-mail: brewing.science@nottingham.ac.uk, Twitter: @UoNBrewing. The International Centre for Brewing Science at Nottingham applies contemporary science and pioneering sensory understanding to deliver outstanding value to the international brewing industry. Our strengths include malting science/technology, yeast and fermentation technology, sensory science, beer flavor technology and part- and full-time Postgraduate Brewing qualifications and short courses.

9 * **White Labs,** 9495 Candida Street, San Diego, CA, 92126 U.S.A.; Telephone: 1.888.5-YEAST-5, Web: www.whitelabs.com, E-mail: info@whitelabs.com, Facebook: www.facebook.com/whitelabs, Twitter: www.twitter.com/whitelabs. White Labs Inc. was founded in 1995 and supplies breweries, wineries, and distilleries with fresh yeast and related products, including analytical services. White Labs was the innovator of pitchable yeast. With offices in San Diego, CA; Davis, CA; Boulder, CO; and soon in Asheville, NC.

THANK YOU VOLUNTEERS

Thank you to all volunteers who help make ASBC a valuable society. A special thank you to the Program Committee for making this meeting possible and to all the officers and committee chairs who pull everything together.

Program Committee

Scott Britton
Duvel Moortgat USA

Patricia Aron
MillerCoors

Kimberly Bacigalupo
Sierra Nevada Brewing Co.

Robert Christiansen
Avery Brewing Co.

Jeffery Cornell
MillerCoors

John Engel
MillerCoors

Cecil Giarratano
MillerCoors

Christine Hansen
E. & J. Gallo Winery

Scott Helstad
Cargill Inc.

Cindy-Lou Lakenburges
Anheuser-Busch, LLC

Karl Lakenburges
Anheuser-Busch, LLC

Rebecca Newman
Consultant

Sylvie Van Zandycke
DSM Food Specialties

Daniel Vollmer
Oregon State University

Christine White
Molson Coors Brewing Co.

Officers

President
Thomas Shellhammer
Oregon State University

President-Elect
Christina Schoenberger
Joh. Barth & Sohn GmbH & Co. KG

Vice President
Christine White
Molson Coors Brewing Co.

Past President
Jeffery Cornell
MillerCoors

Secretary
Kelly Tretter
New Belgium Brewing Co.

Interim Treasurer
Paul Pettinger
New Belgium Brewing Co.

International Director
Roland Folz
Haffmans BV

Committee Chairs

ASBC/MBAA Steering Committee
Christina Schoenberger
Joh. Barth & Sohn GmbH & Co. KG

Christine White
Molson Coors Brewing Co.

Awards Committee
Christine White
Molson Coors Brewing Co.

Finance Committee
Paul Pettinger
New Belgium Brewing Co.

Foundation Board
Annette Fritsch
Boston Beer Co.

Loy Barber
Anheuser-Busch Inc.

International Committee
Roland Folz
Haffmans BV

Nominating Committee
Jeffery Cornell
MillerCoors

Publications Committee
Rebecca Jennings
Rahr Malting Co.

ASBC Buzz
Teri Bellman Garvin
MillerCoors

Journal of the ASBC
Charles Bamforth
University of California, Davis

Technical Committee
Chris Powell
University of Nottingham

Technical Subcommittee Chairs

Beer Filtration Task Force
Aaron MacLeod
Canadian Grain Commission

Can Fill Calculators
Scott Brendecke
Ball Corporation

Check Services
Rebecca Jennings
Rahr Malting Co.

Coordination of New and Alternate *Methods of Analysis*
Joe Palausky
Boulevard Brewing Co.

Craft Brew
TBD

Determination of Wort Amino Acids by HPLC
TBD

Emerging Issues
David Maradyn
Novozymes North America

Hop Analysis by GCMS
Kimberly Bacigalupo
Sierra Nevada Brewing Co.

International Hop Standards Committee
Robert Foster
MillerCoors

International Method Streamlining
Chris Powell
University of Nottingham

Lipoxygenase Activity in Malt
Allen Eastlund
Rahr Malting Co.

***Methods of Analysis* Review**
Mark Eurich
New Belgium Brewing Co.

Rebecca Jennings
Rahr Malting Co.

Karl Lakenburges
Anheuser-Busch, LLC

Microbiological Methods
Caroline Pachello
MillerCoors

NIBEM for Foam Stablity
Mark Eurich
New Belgium Brewing Co.

NIR for Hop Analysis
Robert Foster
MillerCoors

Aaron Porter
Sierra Nevada Brewing Co.

Packaging Methods
Scott Brendecke
Ball Corporation

Rapid Method for Identification of Phenolic Character in Yeast
Trevor Cowley
SABMiller PLC

Rapid Method for Malt Color
Betsy Roberts
Briess Malting Co.

Sensory Science
Lindsay Guerdrum
New Belgium Brewing Co.

Soluble Starch
Rebecca Jennings
Rahr Malting Co.

Wort Color Turbidity Correction
Theresa Chicos
Rahr Malting Co.

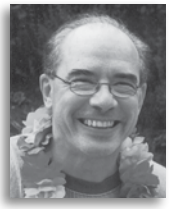
ASBC AWARDS

Award of Distinction

Xiang Yin

This award acknowledges exceptional lifetime achievement, contribution, and service to brewing science and the brewing industry. The 2015 recipient is Xiang Yin of SABMiller PLC.

Honorary Life Member



Brian Williams

This award is reserved for retired members who have exhibited exceptional long-term service to the society within elected or appointed positions. The 2015 recipient is Brian Williams (posthumous).

Eric Kneen Memorial Award

The ASBC Eric Kneen Memorial Award is presented to the author(s) of the best paper published in the *Journal of the ASBC* during the previous calendar year.

The recipients of the 2015 Eric Kneen Memorial Award are Christina Schmidt, Martin Biendl, Annika Lagemann, Georg Stettner, Christian Vogt, Andreas Dunkel, and Thomas Hofmann for their article, "Influence of Different Hop Products on the cis/trans Ratio of Iso-alpha-Acids in Beer and Changes in Key Aroma and Bitter Taste Molecules During Beer Ageing." The article was published in the *Journal of the ASBC* Vol. 72: No. 2 pp 116–125 in 2014.

Christina Schmidt

Martin Biendl

Annika Lagemann

Georg Stettner

Christian Vogt

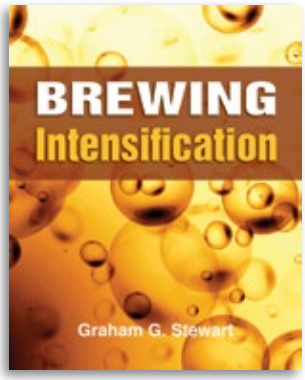
Andreas Dunkel

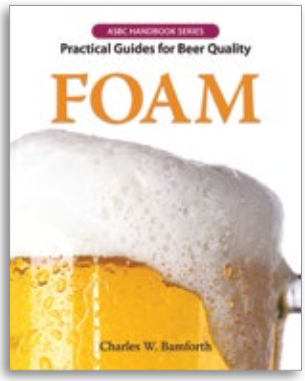
Thomas Hofmann

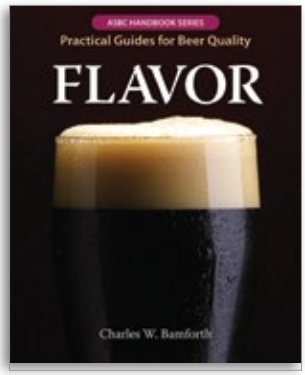
AUTHOR INDEX

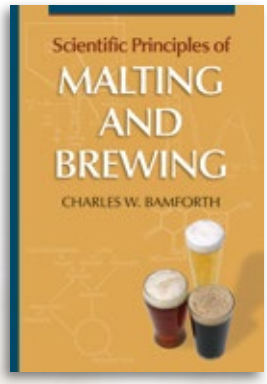
The number following an author's last name refers to abstract number.

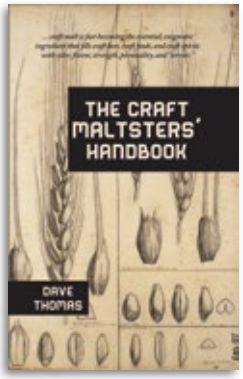
Get your fill of… *knowledge* at the ASBC Bookstore!

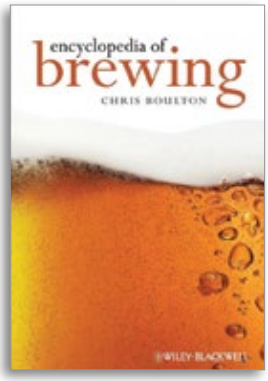












Dozens of titles
NOW ON SALE
in the meeting
registration area!

Up to 20% off!

ROCK THE BREW

worldbrewingcongress.org

WBC 2016

WORLD BREWING CONGRESS

SAVE THE DATE

August 13–17, 2016 • Denver, Colorado, U.S.A.

Hosted by the American Society of Brewing Chemists and Master Brewers Association of the Americas, with active participation by Brewery Convention of Japan, European Brewery Convention, and Institute of Brewing and Distilling