SOCIETY NEWS

THE SOCIETY OF FLAVOR CHEMISTS, INC

President's Message

Mary Foster 2015—2016

Dear Colleagues,

It is an honor and privilege to write this letter as your President. It seems like it was just yesterday that I came onto the SFC Board as Secretary. It's a big deal to me to lead this organization, but over the past few years I have acquired much knowledge from, and will draw from the experience of the Presidents serving before me. With the combined efforts of the current SFC Board of directors, we are sure to have a successful year.

Continued—page 2

In this issue:

Board of Directors 2015-2016

President's Message-continued

Mary Foster 2015—2016

We have a great year ahead of us. Our meeting dates have been established, and are listed on the SFC Website home page. I hope you will join us for one or more meetings this year.

Our first meeting of the Fall will be in Chicago, on September 17th. Cyndie Lipka has contacted for several speakers for our educational program, and will be announcing the venue in the near future.

On October 8th, we will meet in Newark. Wai Lam is our new Arrangements Committee Chair and is already working with the DoubleTree Hotel to secure meeting facilities. Bill Choudhury is our new Program Chair, and is currently seeking speakers. We are also looking into a speaker who was recommended to us by a SFC member.

Our West Coast Committee Chair, Maria Olson, and several SFC members are working on a new meeting for us over the winter. We are excited to be planning on a California meeting in January. We will also continue with our participation in the shared meeting with NAFFS and CSA on the West Coast in March. Details will be available soon, so please check the website often.

February brings us back to Newark, followed by Cincinnati in April and Newark in May for our Annual Meeting.

If you have any thoughts or recommendations for meeting topics, speakers or venues, please contact any of the Committee Chairs with your ideas.

As always, I would like to remind you that the Society of Flavor Chemists is an organization run by volunteers. I encourage you to support the SFC by joining a committee. Remember, joining a committee is the first step in the progression to becoming a Board member. And you all want to serve on the Board, right?!?

Kidding aside, we have a new committee/volunteer opportunity that we need your support with. At our May meeting members in attendance were shown a concept of a shirt and jacket embroidered with the SFC logo. They were well-received, and we would like to move forward with establishing a committee (tentatively named the "Fashion Committee") to take this idea to the next level, making logo wear available for members to purchase. Please contact me directly at president@flavorchemist.org if you would like to help, or if you have any questions. (see page 3)

If you have any problems with the SFC website please contact the SFC Website Committee (not the SFC Administrator).

- Please remember to regularly go into your profile on the SFC website to assure that your contact information is current. We continue to have members who we are unable to contact because their information is inaccurate.

- Please reach out to the SFC Board and Committees if you have any ideas that would benefit the Society. We are always looking for ways to improve and serve our members' needs.

I hope you have a fabulous Summer, and look forward to seeing you in the Fall.

Best Regards,

Mary Foster

Help Wanted:

Fashionable Flavorists

The Society of Flavor Chemists needs your help to work on the **"Fashion Committee."**

We are seeking a Committee Chair and Committee Members to coordinate the effort to outfit our members in stylish SFC logo attire. Time commitment is minimal. The target launch date for orders is Fall 2015.

If you are interested,

or if you have any questions, please contact

Mary Foster at president@flavorchemist.org.

Welcome, New Members!

From the February Meeting

Glenn Kraemer—Apprentice

I began my career compounding a large array of flavors primarily for confectionary and chewing gum applications. Later, I transferred for two years focusing on beverage applications such as teas and sports drinks. For the last four years at Firmenich I have submitted successful solutions for breakfast cereals, oatmeal, yogurt, and cookies. I have also kept active on organoleptic evaluation.

I enjoy travelling to learn about other cultures and cuisines. These experiences have inspired my creativity in the kitchen and the lab. In New Jersey I was a volunteer firefighter, and hope to be involved in the community now in the Chicago area.

Katie Pappas—Full Certified

I work at McCormick as an associate flavor chemist. I graduated from Goucher College with a Bachelor of Arts and Chemistry. I enjoy using both my analytical and creative abilities when designing flavors. Outside of work, I enjoy spending time with my family and watching my one year old son discover the world around him. I also like to ride horses and try out new recipes from the Food Channel.

Welcome, New Members!

From the April Midwest Meeting

Eliana Nogueira de Aguiar Silveira - to Certified, Christine Conlay, Apprentice Chris Wulff, Apprentice

Eliana Nogueira de Aguiar Silveira: I am from Brazil, a graduate of the Methodist University in Industrial Chemistry working for the past 15 years in flavor creation for beverage, sweet goods, confectionary, etc. During my first year of university in1997, a rare opportunity came my way to work as an intern in the quality Control at Degussa Flavor & System. From there I fell in love with flavor technology and was immediately excited to learn everything about it. After that, I was invited to work at the flavor creation laboratory as a technician where I had the great opportunity to be trained. In 2005, I moved to Takasago as a Jr. Flavorist.

I have been fortunate to work with great flavorists from different countries and cultures. They were all very important to my training and professional growth.

I am married with a special person that has supported all my dreams. I love spending time with my family that is everything to me.

Christine Conlay: I hold a Bachelors Degree in Chemistry from the University of Cincinnati. After graduation I began my career in the flavor industry at Mane, where I am still employed. My main focus in on sweet goods, confection, dairy, and oral care. My spare time is spend raising my three children and cheering for them at all of their sporting events. I also enjoy crafts, reading, and volunteering at our local animal shelter.

Chris Wulff: I am 34 years old. I have been working for the flavor industry for over eight years now, and I enjoy it. I am originally from Northwest Illinois where I grew up on a Dairy and hog farm. I enjoy running and weight training, fishing, and metal detecting in my free time. I am currently considering getting a dog, and saving for my first home.

Welcome, New Members!

From the May Annual Meeting

Kay Murano, upgrade to Certified, IFF

Kay Murano. After receiving her BS and MS degrees in Organic Chemistry from St John's, Kay joined IFF in 2005. She progressed as a Flavorist Trainee and Junior Trainee under the Global Research team. There she refereed presentations, and contributed to a number of IFF patents and publications.

In 2013 she received her PhD in Food Science from Rutger's University. Kay was promoted to Flavorist and was able to follow her passion for flavor creation in he Creative and Applications team.

Besides her work at IFF, Kay is on the Board of Directors in the Women in Flavors and Fragrance Commerce as Vice-President

David Gera. David is current a Senior Scientist at Pepsico. He lives in Fairfield, CT with his wife Christine, son Joseph and daughter Stella. He spends most of his leisure time with his family and extended family. Big activities include outdoor activities and traditional Italian dinners. His son learned to snow board so now he has a partner on the slopes.

David also helps his father-in-law in his tree business by climbing and felling trees. He finds the physical outdoor work a welcome contrast to work in the lab . He says he doesn't worry much about the future. He lives for the moment and enjoys the ride!

David Gera, upgrade to Certified,

Eric Diaz, apprentice, Symrise.

Eric Diaz. Eric is a New Jersey native, growing up in Jersey City, NJ and receiving his BS degree at New Jersey City University in Bio/Chem in 2011. He started as a contract employee at Symrise as a flavor lab technician starting in 2003. IN 2006 David was hired at a permanent employee of Symrise. He is currently still working, learning, and growing at the same company. He says he truly enjoys his profession and the industry it represents. David looks forward to the endeavors of the his Flavorist career path that lies ahead of him.

2015—2016 SFC Meetings!

September 17, 2015 – Chicago

October 8, 2015 – Newark

January, 2016—West Coast (TBD)

February 11, 2016 – Newark

March 2016 – West Coast (TBD)

April 14, 2016 – Cincinnati

May 19, 2016 – Newark

VANILLA 2015

Vanillin: Physics, Chemistry, Biotechnology, Business, Application, Regulations and Controversy

November 3 - 5 Monroe, NJ

Vanilla 2015 will be held November 3th-5th, 2015 at the Crowne Plaza Monroe in Monroe, NJ. This meeting will focus on vanillin: past, present and future.

See http://www.vanilla2015.com/ for more details

Committees

Arrangements:

Wai Lan

arrangements@flavorchemist.org

Audit:

Dieter Bauer

audit@flavorchemist.org

Bylaws:

Dolf DeRovira & Jan Ford

by-laws@flavorchemist.org

History:

Veronica McBurnie

history@flavorchemist.org

historian@flavorchemist.org

Library:

Aaron Graham

library@flavorchemist.org

Media:

Shane T McDonald

media@flavorchemist.org

Membership:

Cathianne Leonardi

membership@flavorchemist.org

Mentorship:

Steve Ruocco & Dennis Kucharczyk

membership@flavorchemist.org

Nominating:

Dolf DeRovira

nominating@flavorchemist.org

Scholarship:

Belaynet "Bill" Choudhury

scholarship@flavorchemist.org

Symposium:

Cyndie Lipka

symposium@flavorchemist.org

Webcast:

Lisa Dierbach

west-coast@flavorchemist.org

Website Committee:

Terry Miesle

website@flavorchemist.org

Chicago:

Cyndie Lipka

chicago-meeting@flavorchemist.org

East Coast:

Belaynet "Bill" Choudhury

program@flavorchemist.org

Midwest:

Mike Weller & Dave Wolfenberger

midwest-committee@flavorchemist.org

West Coast:

Maria Olson

west-coast@flavorchemist.org

Get involved in your Society! Consider joining one of these committees!

February Meeting at Monell

A GREAT MEETING IN PHILADELPHIA!

The joined meeting of The Society of Flavor Chemists and The Monell Chemical Senses Center on February 12 was a great success! It was not only a success because we had some 81 attendees, but more importantly the program was spiced with highlights.

Dr. Gary Beauchamp, Emeritus Director of Monell, was installed as an Honorary Member of the Society.

Gary, who for many years has been a strong supporter of the Society, is one of the few scientists in the world who give us the foundation and the understanding of flavor chemistry, so that we as flavorists can do our creative work.

He is one of the world's leading experts on chemosensory science and has authored and co-authored over 300 publications, all of which in one way or another are dealing with flavor.

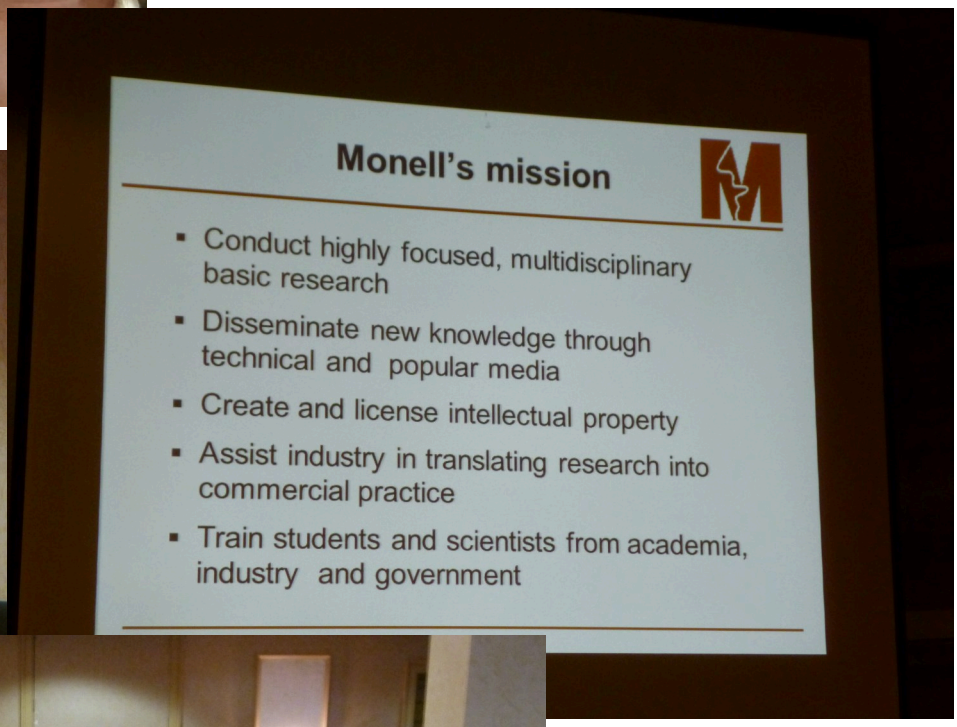
In the afternoon we were updated on the latest discoveries on taste and smell. Robert F. Margolskee, MD, PhD, President and Director of Monell gave us his insight how his leadership in Monell will be "moving from strength to strength". He then gave us a most interesting Review of Sweet Taste Research.

This was followed by excellent presentations by Carol Christensen PhD, Paul Wise PhD, Joel Mainland PhD and Danielle Reed PhD who all covered different aspects of the research on Taste and Smell.

The last part of this most interesting day was a reception in the Library at Monell.

In the up-date of the Library we were informed that the SFC Library received over 300 new additions in 2014 from individuals and from companies. The most significant addition came from IFF of a collection of books that signify the beginning of the flavor industry in Europe. Most of these books are in German and some are in French and Dutch.

They include what are considered the Bibles of an older generation of flavorists, such as Die Atherischen Ole by Gildemeister of which its first volume was published in 1910. As an example of books in French, that are important in the preservation of our


Monell's mission
Conduct highly focused, multidisciplinary basic research
Disseminate new knowledge through technical and popular media
Create and license intellectual property
Assist industry in translating research into commercial practice
Train students and scientists from academia, industry and government

2015 California Meeting

This meeting was called "Unlocking the Future of Healthful Beverages with Flavor, Texture and Nutrition". There were 4 speakers taking about nutritional ingredients in fortified beverages, texturing trends and techniques for healthful beverages, transformation of grains, nuts, seeds and tubers into beverages and the future of healthful beverages.

There were 121 registered attendants. 27 of them are members Society of Flavor Chemists.

Cheryl Mitchell, Ph.D, President –Blue Pacific Ingredient Innovations spoke on the transformation of grains, nuts, seeds and tubers into beverages and healthy drinks and the need for milk replacements.

Jeremy Bartos, Ph.D Scientific & Regulatory Affairs –Glanbia Nutritionals, Inc-discussed the rules of label claims and much more.

Dan Grazaitis, CFS TIC Gums provided helpful information for texture and mouthfeel.

The SFC Members present met and talked about the importance of building up the West Coast Meeting. There were 26 members present-just short of quorum. So, make sure you stick around for he business meeting. We can't vote on new members without a quorum.

Midwest Meeting—Cincinnati OH

The meeting was held at the historic Netherland Plaza hotel in downtown Cincinnati. This Art Deco skyscraper is a truly historic building, and the restored Art Deco settings are beautiful. Alfrebro and Sigma-Aldrich presented new items at the Chem Sources section of the meeting.

Dr. John Paul Maye discussed the chemistry and history of hops. He described some of the interesting chemistry behind hops and brewing. Jeff Parker of Paradune Farms talked about hops cultivation in Ohio, which sells to the craft brewing industry in Ohio. There is lots of interest in hops growing, but a lot of unique challenges as well.

Wenqi Zhu of the University of Illinois won the 2015 Jogue Scholarship for analytical chemistry for flavors, She gave a presentation on her research topic discerning the flavor chemistry of the savory “soy sauce” aroma of maotai, a traditional Chinese spirit used to toast head s of state.

The Chemical Sources Roundtable

Held in conjunction with the CSA Round Table, the Annual Meeting is always one of the best-attended SFC events. This year was no exception. The Round Table event was full, and as hectic as ever. New Natural ingredients caught my attention, many never previously available in that form. New branched fatty acids, nitrogen and sulfur compounds are highlights. An ever-expanding range of natural extracts are also available. New synthetics aren't far behind.

Annual meeting

Our new board welcomes Mike Bloom as Treasurer, and sees Mary Foster assume the Presidency. Deborah Osborne becomes Vice President, Lisa Vaughn remains Secretary and Cyndie Lipka becomes the new Chair. Several new Committee Chairs begin their tenure, our financial situation is good, and we continue to induct new Members at a fairly constant rate. At this meeting Kay Murano and David Gera upgraded to Certified and Eric Diaz is a new Apprentice. Several members were recognized for 25 years in the industry, present were Ed Krutal and Dean Wilson.

Some new modifications to our Bylaws were outlined. All modifications have to do with the status of members who are training individuals either for Apprentice level certification or fully Certified levels. Those mentors must be members "in Good Standing or Emeritus" level during the entirety of an individual's training. This is a further effort to tighten our certification efforts.

Mary Foster has been investigating some SFC apparel, and is looking for a couple of volunteers for the self-described "Fashion Committee" to help bring this project to fruition (see page 3). The prototypes included shirts and a nice neoprene jacket. They will be available for sale later this year, hopefully.

2015—2016 Society of the Flavor Chemists Board of Directors. Our new board welcomes Mike Bloom as Treasurer, and sees Mary Foster assume the Presidency. Deborah Osborne becomes Vice President, Lisa Vaughn remains Secretary and Cyndie Lipka becomes the new Chairperson.

2015-2016 SFC Board. Right to Left: Lisa Vaughn, Secretary; Michael Bloom, Treasurer, Cyndie Lipka, Chair; Deborah Osborne, Vice-President; and Mary Foster, President

2015 Jaggar Scholarship Winner: Wenqi Zhu

Wenqi is currently pursuing a doctorate in food science with a concentration in flavor chemistry at the University of Illinois at Urbana-Champagne.

2015 Jogue Scholarship Winner: David Potts

David Potts was our Jogue Scholarship winner. He's a student at Minnesota investigating the creamy nature of foods. Discounting fats and some protein structures, there are still "creamy" compounds which are difficult to identify. These may work in concert, or may even block bittering compounds to intensify creaminess. It's interesting work, and not a simple matter to separate variables.

David is currently pursuing a doctorate in food science under the supervision of Dr. Devin Peterson at the University of Minnesota, Twin Cities. His research topic is: "Characterization of the Key Flavor Compounds (Aroma and Taste) Responsible for the Creaminess Perception of Dairy Products."

What's in a Name?

Cathianne Leonardi

'What's in a name? That which we call a rose by any other name would smell as sweet' is a widely recognized line from Shakespeare's Romeo & Juliet. Juliet Capulet, a young strong willed Italian woman of privilege, declares it while pondering the feelings she has for a young man who bears the surname of her family's sworn enemy. Her declaration of 'What's in a name?' predicts an open willingness to delve deeper into the character of the person beyond the name.

Flavorists employ a willingness to explore the meaning of names and intimately know the items the name represents. 'What's in a name?' is precisely the question asked when one recognizes IUPAC nomenclature. Hexanoic acid, a flavoring item often used in sweet and savory flavorings, owes the hexa- prefix of its name to the Greek root for 6. Flavorists use this to understand the chemical structure contains 6 carbons. This is eerily similar to the preschool acquired knowledge that a hexagon contains 6 sides. We all most likely licked and loved a plastic hexagon at some point in our lives yet may have initially squirmed at the thought of considering the amount of carbons found in chemicals.

Hexanoic acid may also be referred to as caproic acid. This name derives from the Latin root caper, capr-, meaning goat. Latin being another subject of love or hate developed in formative years. In the mind of a Flavorist this name has meaning as the taste of caproic acid can be described as goaty, with the acid itself identified in goat milks and cheeses. Other acids found in goat milks and cheeses include caprylic and capric acids. What's in these names provide insight into taste expectations and opportunities for use of the items in flavorings.

Commonly used industry names of some materials can foreshadow taste expectations as well. Raspberry ketone and vanillin are otherwise known respectively as 4-(4-Hydroxyphenyl) butan-2-one and 4-Hydroxy-3-methoxybenzaldehyde. The commonly used names act as a reflection of where the items have been found in nature while the chemical names denote structure. These pieces of information linked together in a Flavorist's knowledge bank can determine where to best use the items, choice of solvent and solubility expectations.

Sometimes what's in a name can preface a need for secrecy of the item in our industry. Trade names like 'strawberiff' refers to 2 -methyl- 2-pentenoic acid, while 'aldehyde c-18', indicates a lactone; specifically gamma nonalactone. 'Aldehyde c-16' is also referenced as 'strawberry aldehyde' while its chemical identity is ethyl methylphenylglycidate. These items were assigned misleading names to disguise origins and protect ingenuity. By learning them, Flavorists can gain understanding of industry confidentiality.

Holding flavor formulations in strict confidence is demanded by Flavorists. Privacy practiced has much to do with the absent ability to patent flavoring formulations. We develop tastes for loved food brands, the brands are the property of another entity, and our flavorings become the privileged use of that entity to deliver great tastes to consumers. Because we fully accept this unwritten contract of our labor, Flavorists greatly respect the need for discretion.

While our heads easily follow the need for confidentiality our hearts also play a part in flavor creation. French for heart, coeur, finds its name on flavoring items including linalool, geraniol and citronellol. Each of them has an ability to add floral characters to fruit flavorings when used in imaginative ways while referencing the role of French perfumery in characterizing aroma chemicals. French perfumery was after all inspired by another strong willed Italian woman: Catherine de Medici.

The Natural, Clean Label, Wholesome, Simple and Transparent Trend

Trends come and go, come and stay, and then they come, go and come back again. The once fashionable Atkins/no-carb diet forced bakeries to close. Natural Greek yogurt is now so highly favored that most major yogurt brands have a Greek yogurt line. In the 1980's a clear beverage, free of artificial colors and preservatives, "The Original New York Seltzer", prevailed in the market but shortly disappeared. With the resurgence of the "clean, chemical free" trend, though, the Original New York Seltzer has decided to try for a comeback this spring.

The natural, clean label, chemical free trend is alive and strong. Pizza Hut, Taco Bell, Panera, Nestle and General Mills are just some of the food manufacturers announcing that they will no longer use artificial ingredients, but rather use simple ingredients, natural ingredients and be transparent. From a conversation with a supplier to Panera, they had adequate notice from Panera to modify their products. Decisions to change were not made randomly or based from emotion.

For any scientist, the idea that food is "chemical free" or that "natural" is safer is silly. It's laughable that the ability to pronounce something makes it "healthy". None the less, whether or not the descriptors are well defined or ill-chosen is irrelevant, we understand what consumers want and we are creative enough to meet their demands. Consumers want to be healthier and make good food and drink choices for themselves and their family. They would like food and beverage manufactures to hold some responsibility for being able to offer "healthy" food choices.

The majority of households in the United States are food secure and therefore have their basic needs for food and nutrition met. They have the luxury of being able to question the food they chose to buy and consume. Transparency is a trend that may come and stay. The flavor industry must decide what is proprietary and what should be freely shared. As flavor chemists, we know that flavor formulas and products are fairly easy to copy, but having a trusting relationship with customers is often the most difficult part. Keeping secrets is not be the best way to keep consumers happy.

Susie Bautista, www.flavorscientist.com

Application of Metabolic Engineering for the Flavor Industry

Shane T McDonald PhD

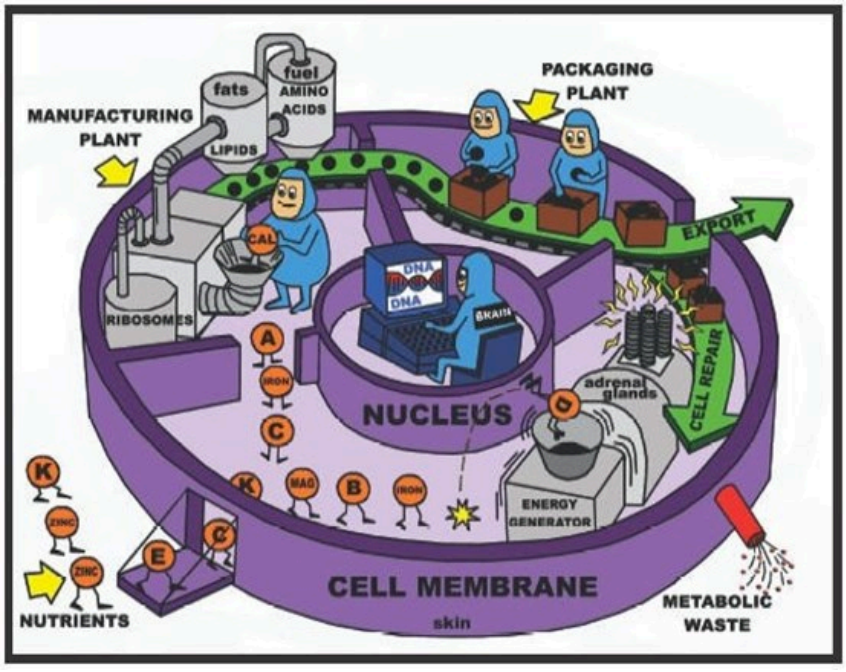
Metabolic Engineering (MBE) refers to a technology in which converts micro-organisms into chemical factories. It is the targeted and purposeful alteration of metabolic pathways found in an organism in order to understand and utilize cellular pathways for the production of chemical compounds of interest. The engineer examines enzymatic pathways and intermediates that form compounds of interest (IMBE, 2015). Then the genes are manipulated to remove or reduce roadblocks to the production of the compounds of interest. It is somewhat different from synthetic biology in that the enzyme systems in MBE uses existing enzymatic systems and removed bottlenecks to greater production of target compounds. In contrast, synthetic engineering brings in new enzymes to produce totally different compounds (VanLang, 2015).

This article discusses applications of MBE that would be of interest to flavor chemists.

Some of the metabolic pathways of interest involve the enzymes where carotenoid and lycopene synthesis branch off from terpene synthesis. . Terpenes are an important source of flavor compounds, especially in herbs and spices (Mahmoud & Croteau, 2002, and Lange & Ahkami, 2013).

Therefore, these enzymes and their regulation are studied carefully to determine the best way to increase the production of specific terpenes. The traditional plant might not be able to amenable to high efficiency terpene production. In order to increase production of terpenes, the enzymes may be transferred to a host organism. The typical terpenes are an important source of flavor compounds, especially in herbs and spices (Mahmoud & Croteau, 2002, and Lange & Ahkami, 2013).

Let's take a closer look. There are four stages to terpene biosynthesis. The first creates the universal precursors; isopentenyl disphosphate (IPP) and dimethylallyl diphosphate (DMAPP) via either the Mevalonic Acid or the 2C-Methyl-D-erythritol-4-phosphate pathways. The second condenses the two precursors IPP and DMAPP to form geranyl diphosphate. The third stage forms the terpene core structure (such as limonene) and the fourth stage modified the parent terpene to form the myriad of terpenes found in natural plant extracts. MBE examines the synthetic pathways and enzymes to find ways to increase production of target compounds. For instance, if the rate-limiting step is the production of DMAPP or IPP, those enzymes responsible could be over-expressed in the plant, or the enzyme placed in another organism that can tolerate larger quantities of the compounds. Enzymes in stage 4 could be stimulated and competing enzymes suppressed to favor one terpene product over another (Lange & Ahkami, 2013). Following are some examples.



Application of Metabolic Engineering for the Flavor Industry Cont'd

Increasing mint oil yields and mint oil composition: Peppermint plants (*Mentha piperita* L) produce a number of important terpenes, most notably menthol, from isoprenoids. The first step of isoprenoid precursors is moderated by enzyme DXPS[1], producing the compound DXP[2]. DXP is a precursor to several branches of metabolic activity also producing thiamine and carotenoids. A second enzyme, DXR[3], regulates the first committed step for isoprenoid production, so is a major point for controlling terpene production. Researchers are able to use transgenic methods to modify this enzyme to create plants with 50% more essential oil than traditional plants. A different enzyme, MFS[4], can be modified to decrease the production of the sometimes undesired compound menthofuran (Lange et al, 2011, Lange & Ahkami, 2013, Mahmoud & Croteau, 2001).

Spike lavender (*Lavandula latifolia*) is an herb mostly used for its essential oil. The major constituents of the essential oil are the terpenes eucalyptol, linalool, and camphor. Genes regulating the DXS enzyme are taken from the *Brassicacaceae* (mustard and cabbage) and transferred to spike lavender via the vector in tobacco mosaic virus. This resulted in an increase in essential oil yields in the leaves of 100 to 350%, and 12 to 74% increase from the flowers (Munoz-Bertomeu et al, 2006).

Other terpenes that have been made with MBE techniques include linalool, geraniol, neral, limonene, citronellol, and zingerberene.

Let's look at an example of sesquiterpene synthesis. Sandalwood (*Santalum* species) is prized for the fragrant oil from the heartwood. The most important fragrance compounds are a series of santalols, which are sesquiterpenes. The tree is slow to mature and the global supply has been threatened by the unsustainable harvesting and cultivation practices. It is included on the CITES (Convention on International Trade in Endangered Species of Wild Flora and Fauna) list as an timber species which are ***not*** necessarily threatened with extinction, but may become so (USDA). Therefore, santalols are a good candidate for metabolic (Diaz-Chavez et al, 2013). Key enzymes responsible for santalols are also responsible for 90% of the essential oil of *Santalum album*. These enzymes are transferred to bioengineered yeast cells that can produce these compounds in large quantities. It is believed that MBE would reduce pressure on the supply of sandalwood in native forests.

In conclusion, MBE can be used to greatly increase the key flavor compounds of interest to the flavor industry. The potential downfall is the perception of genetically modified organisms (GMO). A company would have to gauge the likelihood of significant consumer backlash as these products using artificial enhancement and transgenic technology.

[1] 1-deoxyD-xylulose 5-phophate synthase
[2] 1-Deoxy-D-xylulose-5-phosphate
[3] Deoxyxylulose phosphate reductoisomerase
[4] (+)-Menthofuran synthase

References

Diaz-Chavez, M., Moniodis, J., Madilao, L., Jancsik, S., Keeling, C., Barbour, E., Ghisalberti, E., Plummer, J., Jones, C., and Bohlman, J. 2013. Biosynthesis of sandalwood oil: *Santalum alba* CYP76F cytochromes P450 produce santolos and bergamotol. Plus one. DOI 10.137/journal.pone.0075053.

International metabolic engineering society (IMES). 2015. http://www.journals.elsevier.com/metabolic-engineering/

Lange, B., Mahmoud, S., Wildung, M., Turner, G., Davis, E., Lange, I., Baker, C., Boydston, R., and R. Croteau. 2011. Improving peppermint essential oil yield and composition by metabolic engineering. PNAS. V108, #41., 16944 – 16949.

Lange, M., and Ahkami, A. 2013. Metabolic engineering of plant monoterpenes, sesquiterpenes, and diterpenes – current status and future opportunities. Plant biotechnology Journal 11 (169 – 196).

Mahmoud, S., and Crouteau, R. 2001. Metabolic engineering of essential oil yield and composition in mint by altering expression of deoxyxylulose reductoisomerase and menthofuran synthase. 2001. Proceedings of the national academy of sciences of the United States of America, Vol. 98 (15) pp 8915 – 8920.

Mahmoud, S., and Crouteau, R. 2002. Strategies for transgenic manipulation of monoterpene biosynthesis in plants. Trends in plant science. 1360 – 1385.Mahmoud, S., and Croteau, R. 2015.

Munoz-Bertomeu, J., Arrillaga, I., Roc, R., and Segura, J. 2006. Up-Regulation of 1-deoxy-D-xylulose-5-phosphate synthase enhances production of essential oils in transgenic spike lavender. Plant Physiology. 142(3): 890-900.

United States Department of Agriculture. 2010. CITES I – II – III timber species manual.

Vanlang, C. 2015. Quohora. http://www.quora.com/Whats-the-difference-between-metabolic-engineering-and-synthetic-biology