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Driving safer products through collaborative innovation Lessons learned from the Green Chemistry & Commerce Council's collaborative innovation challenge for safe and effective preservatives for consumer products

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ABSTRACT

Whether responding to retailer, government, consumer, or advocacy pressures to eliminate chemicals of concern from their products or position themselves in the growing sustainable products space, many brands are on the constant lookout for new safe, effective chemical ingredients for their products. Increasingly brands are willing to set aside their competitive instincts to collaboratively search for, develop, evaluate, and push to market new green chemicals for which they share a common need. This article analyzes "collaborative innovation" initiatives of the Green Chemistry & Commerce Council (GC3), a business organization focused on accelerating the commercialization of green chemistry solutions. In particular, the article explores in detail lessons learned from the GC3's Collaborative Innovation Challenge on Safe and Effective Preservatives, which convened two retailers, eleven brands, and six chemical suppliers to identify new, sustainable preservative options for consumer products. These efforts have found that collaborative innovation is most effective when there are strong market or policy signals to act and solutions do not confer any particular competitive advantage. They have shown that companies see benefit in collaboration to solve chemistry challenges as such collaboration can accelerate innovation by providing a strong demand signal, sharing knowledge to overcome development challenges, de-risking investment and ultimately lowering costs.

1. Introduction

Whether trying to grab a piece of the green products market or responding to retailer, government, consumer, or advocacy pressures to eliminate chemicals of concern from their products, like certain flame retardants, many leading brands are on the constant lookout for new safe, effective, and perhaps "natural" chemical ingredients or materials for their products. And some brands are willing to set aside their competitive instincts to collaboratively search for, develop, evaluate, and push to market new green chemicals and materials for which they share a common need, for the benefit of all. The Green Chemistry & Commerce Council (GC3) has established a unique approach, called "Collaborative Innovation" to convene consumer products value chains to exploit opportunities to collaboratively solve chemistry challenges. The GC3 defines collaborative innovation as collaboration of multiple competing firms and others in the supply chain, to jointly address a common technology challenge.

For example, in 2012–2013 GC3 conducted a collaborative hazard assessment of alternative plasticizers for wire and cable applications involving a number of chemical suppliers, formulators, and brands in the electronics sector (Morose and Becker, 2013). From that work, we identified a number of key lessons for improving collaborative supply chain efforts to drive innovation, including: (1) identifying approaches upfront to effectively address concerns regarding confidential business information and ownership of intellectual property shared, received or developed during the project; (2) ensuring adequate resources for project management which can take considerable effort; and (3) providing clear guidance at the beginning of the project on approaches taken to evaluate alternatives, data needs, and potential risks to solutions providers (for example if their technology receives a toxicological review indicating concerns). In 2016, the GC3 initiated its Collaborative Innovation Challenge on Safe and Effective Preservatives, which ultimately engaged two major retailers, 11 brands and 5 chemical suppliers. Through this and other collaborative GC3 efforts, we have identified a

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number of critical factors creating incentives for competitors to collaborate on innovation in the consumer products space and lessons learned about the benefits of such collaboration in accelerating commercialization of more sustainable product ingredients. This article provides an overview of the challenge and lessons learned in driving collaborative innovation in the future.

2. Material and methods

This article draws on findings from a number of collaborative innovation projects undertaken by the Green Chemistry & Commerce Council (GC3), a multi-stakeholder collaborative of 130 companies and other thought leaders that drives the commercial adoption of green chemistry by catalyzing and guiding action across all industries, sectors, and supply chains. In particular for this article, we draw from the GC3's Collaborative Innovation Challenge on Safe and Effective Preservatives. The Challenge program convened brand-owners and retailers to develop and execute a collaborative challenge (i.e., crowdsource competition) to identify promising, novel preservative technologies with improved health and safety profiles for their cosmetic and consumer products, jointly evaluate them for performance and safety, and support their commercialization and scale-up. These sponsors – companies providing financial support to the competition (see Box 1) - were involved in designing the overall structure of challenge, developing detailed performance and safety criteria (Green Chemistry & Commerce Council, 2016), reviewing submissions and results of performance validation and safety screening, judging and selecting winners. The GC3 worked with InnoCentive, an open innovation and crowdsource platform service provider, to run the challenge.

The challenge drew 48 technology submissions from around the globe, submitted by small companies, government research labs, and individual entrepreneurs and scientists. The submissions were judged by a panel of expert microbiologists, product formulators, and safety experts from sponsoring CPG companies and other experts. Following an environmental health and safety screen, seven finalists were evaluated for performance by a contract formulator that formulated samples of the seven preservatives into three simple products and subjected the samples to an industry standard test for preservative efficacy. After reviewing the results from the assessments and hosting a pitch competition with the seven semi-finalists, the judges divided the $175,000 prize pool among the seven innovators (see Box 2). These innovators also received the results from the safety and performance evaluations. A networking reception to facilitate connections between the seven innovators and sponsors was held at the 2018 GC3 Innovators Roundtable. The GC3 then contacted individual CPG and supplier sponsors to facilitate further testing and potential partnerships with specific solution providers, based on an understanding of needs and technology offerings, respectively.

Following the competition, we conducted a survey and series of interviews with competition sponsors and solution providers (solvers). Seventeen solution providers and three sponsors responded to the survey. Additionally, two open discussions sessions were held to review the competition experience during the 2018 and 2019 Green Chemistry & Commerce Council Annual Innovators Roundtables.

3. Results

The competition resulted in 48 submissions from around the globe, representing a wide range of synthetic and bio-based chemistries and technologies. While some were early stage developments, such as technology concepts derived from a predictive model or laboratory experiment, a large percentage of the submissions were at pilot stage while only a few were already market-ready or nearly there. A number of the submissions had significant health and safety concerns that eliminated them from further evaluation. And performance testing yielded mixed results in terms of anti-microbial efficacy given the challenges of testing early-stage technologies, in standard formulations, in a commercial testing lab.

Follow-up survey and interviews with solution providers indicated a number of agreements with Competition sponsors and others to further test and evaluate their solutions. Nine noted some kind of development with their technology including additional refinements and toxicological or preservative challenge testing. Four of the technologies are commercially available (including one planning to launch in 2020). One

Box 1
GC3 Preservatives Collaborative Innovation Challenge Sponsors

Category 1 Corporate Sponsors – Designers and judges of the competition.

- Babyganics
- Beautycounter
- Beiersdorf
- Colgate-Palmolive
- Johnson & Johnson (J&J)
- Kao USA
- Method – People Against Dirty
- Procter & Gamble (P&G)
- Reckitt Benckiser (RB)
- SC Johnson
- Target
- Unilever
- Walmart

Category 2 Supplier Sponsors - Preservative suppliers that could take solutions to scale but were not part of the judging process.

- Dow Microbial Control
- Lonza
- Schülke
- Symrise
- Thor

Box 2
GC3 Preservatives Collaborative Innovation Challenge Semi-Finalists

First place award recipients:

- Avisco Ltd.
- IMD Natural Solutions GmbH
- Irena Jevtov Research & Innovation
- United States Department of Agriculture/People Against Dirty/Berkeley Center for Green Chemistry/University of Victoria/Safer Made

Second place award recipients:

- Hydromer, Inc.
- Russian Academy of Sciences

Third place award recipient:

- Chinova Bioworks

Source: https://greenchemistryandcommerce.org/documents/Preservatives%20Challenge%202018%20Winners.pdf.

solution provider summed up the challenges they face in gaining market for their product, stating "multi-million dollar investment to set up large scale cultivation, production and commercialization is needed and very few venture capital funds are interested in green chemistry." One solution provider, which had a technology already on the market, decided to repurpose its preservative for food markets rather than consumer products. Despite these challenges, most of the solution providers indicated an interest in continued dialogue with CPG companies and suppliers in the GC3.

The three sponsors who responded to the survey had all tested at least one of the semi-finalist solutions and had provided feedback to solution providers on testing results (most of the sponsors in one-on-one discussions indicated that they had conducted additional testing on at least one of the awarded solutions). Two of the companies are still in discussions with challenge solution providers. One, a chemical supplier, noted that none of the options met the company's technical requirements. All of the sponsors indicated the need to have better data on the state of development of the solutions as many were inconsistent and variable in quality. An indirect benefit for all three sponsors was that they were approached by companies with new green chemistry solutions that were not part of the competition but inspired by it. One sponsor noted that additional follow-up between sponsors and solution providers would be helpful to address technical challenges encountered and help accelerate the development and commercialization process.

Overall, sponsors and solution providers found the competition a valuable experience to learn about available solutions and receive important feedback from customers, to share experiences about the challenges in bringing new preservatives to market and strategies to address them, and to drive new green chemistry opportunities and thinking.

3.1. Discussion - What's driving increased collaboration among consumer products companies?

While regulatory pressures, particularly in Europe, are playing an important role in driving major brands to evaluate and substitute ingredients of concern for health and environment in their products, market pressures caused by more educated consumers and savvy advocacy campaigns are proving to be an even greater driver (Geiser et al., 2015). Advocacy organizations are increasingly effective at targeting major brands and retailers to both be more transparent about the ingredients in their products as well as to eliminate chemicals of concern. They often highlight gaps in government oversight as a key reason for action. This is having a ripple effect throughout the entire value chain. Take for example, the results of Greenpeace's DeTox campaign which targeted major brands in the footwear and apparel sector for their contamination of waterways in Asia (Grappi et al., 2017). That campaign led to commitments by major brands to eliminate chemicals of concern from their supply chains as well as to establish a new organization, the Zero Discharge of Hazardous Chemicals (ZDHC) collaborative where firms are working to standardize approaches to measuring progress in reducing hazardous chemicals from their supply chains as well as to collaborate on safer substitutes.

In the consumer products space, there have been mounting health and safety concerns about a number of formulated product ingredients such as preservatives, including parabens and formaldehyde, that are used to control microbial growth and prevent contamination. Government regulations in the European Union and other regions have restricted the use of certain preservatives (also called biocides) in formulated products. And importantly, large retailers such as Walmart, Target and CVS have developed chemicals policies restricting certain preservatives from the products that they sell (Bomgardner, 2015). In 2015 Walmart and Target hosted a major workshop that convened its suppliers to provide a clear signal as to their intentions of regulating specific chemicals – including preservatives – in the products they source and the need for companies to work together towards solutions (Clancy, 2015).

Collaborative innovation presents an opportunity for companies to more effectively and rapidly respond to market and regulatory drivers with more sustainable solutions.

Baldwin and von Hippel note that the dominant "producers model" of innovation, where innovations originate from the producers (and are supplied to consumers), driven by the expectation of profits is being replaced by user-driven, open, and collaborative innovation (Baldwin and von Hippel, 2011). This is in part due to reductions in research capacity in many large companies and a realization that innovation efforts focused outside the firm may identify novel technologies or capacities that the larger firm does not possess. Many consumer products and chemical manufacturing firms are engaging in open innovation processes to solve sustainability challenges. Some companies, such as Unilever and Nouryon (formerly AkzoNobel), have created their own open innovation programs, while others are partnering with open

innovation companies such as Nine-Sigma and InnoCentive to identify new product offerings such packaging from renewable feedstocks or specific ingredient solutions that respond to regulatory or market challenges. For example, Nouryon's Imagine Chemistry program organizes an annual start up competition based on identified technology needs; the company then provides support to the winners to bring their technologies to market. For the 2018-19 Imagine Chemistry challenge, Nouryon partnered with Unilever to bring novel, more sustainable surfactants for consumer products to market (Nouryon, 2019).

Like open innovation, collaborative innovation has its roots in the rapid development of IT technology. It is only vaguely defined in the literature, however. A 2015 report by the World Economic Forum noted that 62% of European firms surveyed found that at least 25% of their revenues to be generated from collaborative product and service innovation, and this figure is expected to grow (WEF, 2015). Research has demonstrated a number of benefits of collaborative innovation, including development of more disruptive innovations, more targeted R&D from increased supply chain signals, reduced R&D and production costs (including cost sharing), reduced time to market, and enhanced reputation and market position. Collaborative innovation is particularly beneficial when bringing together the capabilities and challenges of both young, dynamic firms (which have greater flexibility, nimbler response, and niche technical proficiency) and more established companies (which have resources and more sophisticated IP, regulatory, and market resources). A 2009 white paper and survey by the consultancy Kalypso found a number of challenges to collaborative innovation in the consumer products space, including protection of IP, executive level commitment, common goals and interests, and trust building (Friedman and Angelus, 2009). Nonetheless, to date, most collaborative innovation efforts in the consumer products space involve only a small number of collaborating companies, for example one retailer, one brand, and one small supplier company.

Collaborative innovation can involve both R&D in new options as well as addressing challenges to adoption and scale of existing or on-the-horizon solutions. Despite identified challenges, a collaborative innovation approach – where a number of companies across the value chain collaborate - is feasible and advantageous in many cases. Through our work with leading brands in pursuit of safer chemistries, we have identified several conditions that create a situation where companies feel comfortable and see an advantage to working together to solve common chemistry challenges.

1. **There is a strong driver to find a new chemical alternative.** Collaboration takes significant time and there is always some risk that a company's intellectual property will leak out or that a collaborating competitor will gain greater advantage (for example capturing a specific viable technology solution for themselves). We have found that the benefit of collaboration can outweigh these factors in a number of situations: (1) When a regulation restricts or bans the use of a critical chemical in a product; (2) when a retailer seeks to restrict the use of a chemical for products on its shelves; (3) when advocacy organizations undertake campaigns that red flag chemicals or consumer products containing a chemical they deem toxic; and (4) when a brand decides they no longer want to utilize a chemical that they (or the market) deems unsafe. In these situations, companies are under some duress and for some, the potential benefits to collaboration outweigh the potential risks.
2. **There is a need to move relatively quickly to respond to regulatory or market demands.** Regulators and retailers may impose strict timelines for actions to replace ingredients of concern in products. These timelines are often much shorter than those necessary for sustainable ingredient research and development (including regulatory approvals and reformulation challenges). For example, when Johnson & Johnson went to reformulate its iconic Baby Shampoo to remove a preservative byproduct, it took several years and millions of dollars to achieve the golden color that is critical to the brand (Thomas, 2014). A rush to substitute ingredients of concern in response to retailer or regulatory demands, often with an off the shelf, drop-in substitute, can not only negatively impact product quality or performance but also it can result in a regrettable substitution. For example, major brands substituted the chemical bisphenol-a in drinking bottles following market pressures but the substitute bisphenol-s was actually just as problematic (Rochester and Bolden, 2015). In the case of our initiative, preservatives play an important role in products such as shampoos, hand creams, and laundry detergents to slow microbial growth. Yet due to market and regulatory pressures there was an urgent need for new preservative technologies, as the palette of acceptable preservatives that CPG (Consumer Packaged Goods) companies could use had significantly shrunken. Since preservatives often need regulatory approvals and reformulation could pose technical challenges, firms could benefit from collaboration that accelerates R&D and commercialization processes
3. **The technology does not confer particular competitive advantage.** A cosmetic company would be highly unlikely to collaborate with a competitor to search for a new, plant-based anti-aging ingredient and an athletic footwear company would likely never partner with a competing brand on the development of a new bio-based cushioning material for a sneaker sole. And companies may not want to collaborate right away if they have invested significant resources into developing a new, greener technology – even though they may open up that technology at a later point in time to gain benefits from economies of scale (O'Rourke and Strand, 2017). However, major brands are showing an appetite for collaboration when the target chemical or material is common to products sold by multiple brands, is necessary for the product, but does not confer particular competitive advantage for the product. Our work with companies across sectors has identified a number of chemistry challenges ripe for collaboration including: preservatives in cosmetic, personal care and household cleaners; flame retardants in electronics products; plasticizers in flooring and screen printing inks; and cross linking agents in textile coatings (Green Chemistry & Commerce Council, 2019).

3.2. *How do firms benefit from collaboration?*

Large cosmetic, personal care, household, apparel, footwear, electronics and other consumer product companies have their own internal R&D teams working on new chemicals and materials, many have technology scouting teams, and some employ their own or third party open innovation platforms. But in many cases, collaborative innovation can offer several distinct advantages:

1. **An amplified demand signal for technology scouting efforts.** When firms join forces to collaboratively scout for new technologies, the demand signal to the innovation community is strong and gets the attention of both entrepreneurs and established suppliers. We saw this when we staged our Preservatives Collaborative Innovation Challenge with 13 company names attached to it, including Johnson & Johnson, Unilever, Proctor & Gamble, and Colgate Palmolive, and received 48 submissions from around the world. The engagement of major brands and retailers provided a clear signal that engaged five chemical companies interested in new technologies to add to their portfolios. The amplified demand signal can additionally have the effect of accelerating time to market of innovative solutions.
2. **Pooling know-how to get more robust results.** Collaborative innovation creates a platform for experts to share (within certain bounds) knowledge on safety profiles and performance of potentially greener chemical and material substitutes. Technical professionals in competing firms rarely have the opportunity to exchange information in this way. In our collaborative challenge on preservatives, microbiologists, toxicologists, formulators, and regulatory specialists

judging preservative technology submissions engaged in rich discussions about prior testing of similar technologies, safety concerns, and anticipated regulatory action on classes of chemicals around the globe. This allowed the judges to efficiently prioritize certain technologies and drop others from further consideration.

3. **Pooling resources to lower per company costs.** Going it alone can be expensive and smaller firms may not have significant R&D resources. For firms in need of the same or very similar technologies, it is efficient to pool funds to cover the costs of technology scouting service providers, as well as initial performance evaluations and toxicological testing.
4. **De-risking new technologies.** Having a team of experts from a diverse group of companies reviewing and discussing the results of performance testing and safety assessments can lead to a more robust outcome and help to de-risk future technology adoption decisions made by individual firms.
5. **Pushing the innovation accelerator.** In the case of our collaborative challenge on preservatives, the inclusion of smaller, "greener" firms played an important role in influencing the development of criteria for safety as well as the range of alternative technologies evaluated. These firms are frequently more responsive to consumer concerns and have more stringent, cautious criteria regarding chemical hazards to avoid. Larger firms tend to be relatively conservative in ingredient replacement – favoring smaller, "science-based" changes in technologies that often use similar chemistries – whereas smaller firms, which need significantly smaller supplies of ingredients, may be more willing to take risks in exploring novel technologies (Thakar, 2013). These "alpha movers" can provide a proof of concept that can de-risk later investment by larger firms. As a result, in the case of our collaborative innovation challenge, there was a strong interest in both incremental innovations that could be commercialized at scale in a relatively short time as well as more early stage novel innovations in preservative technologies (Corstjens et al., 2018).

4. Conclusions

Collaborative innovation efforts, involving multiple firms to solve a chemistry innovation or adoption challenge, are not easy (Swink, 2006). There is significant upfront engagement, trust-building process, and research needed. For example, while there may be significant disagreement between firms regarding whether an incumbent chemistry is problematic from an environmental or health perspective, consensus on the need for innovation in that chemical function or class is a necessary first step. Additionally, convening 11 brands and two retailers, with widely different cultures, requires individual company outreach and significant upfront discussions on issues regarding intellectual property protections, sharing results, and anti-trust. In particular, concerns about one company in a collaborative innovation project "taking" a particular technology for themselves are real and require agreement as how and when information is shared and how contacts with innovators are made. There is a need to build agreement on criteria for performance, health and safety and sustainability of innovations and the process by which innovations will be reviewed and judged. As a result, transparency as well as regular, open dialogue and contact between partners are key prerequisites for success in such projects. A trusted convener and collaboration with additional partners who have expertise in open innovation challenges, toxicity assessment, and performance assessment are important to overcoming some of the challenges identified in execution of such efforts as well as ensuring independence of results.

We found the challenges in establishing a multi-company collaborative innovation challenge are far outweighed by the many benefits. While brand owners' participation was principally motivated by a desire to get new technologies to market for their products, they benefitted from significant peer learning as experts from each company shared opinions and questions on the new technologies; how they evaluate new technologies; insights on new technologies that each company has tried, which ones worked, which ones did not and why. The suppliers viewed this effort as a powerful technology scouting opportunity, a chance to take measure of their own technology R&D efforts, as well as a chance to gain deeper insight into the desires of their direct customers. The innovators gained significant visibility for their ideas and technologies as well as the potential for investment and partnerships with the brands and suppliers. For the innovators, the prize money from our competition was less important than the connections to market leaders. In the end, by "outsourcing" R&D, the collaborative challenge provided an opportunity to explore innovative technology options to solve a chemistry challenge for which existing options were not considered viable, sustainable long term solutions.

Currently, some of the sponsors are engaged in direct dialogue and further testing with the innovators, but the level of joint development efforts we had expected did not materialize. This may be related to the early stage nature of many of the technologies. Also, the commercialization of new preservatives requires significant performance and safety testing as well as government approvals, creating a long runway, of at least several years, to get a new product in the market. By design, we facilitated rather than managed the terms of these engagements, allowing the innovators and sponsors to find mutually beneficial arrangements. Nonetheless, in our project evaluation, we realized the important need to continue convening sponsors to address commercialization barriers. To address this follow-up need, the GC3 is in the process of establishing a new Commercialization Hub, which will develop strategic business plans to address barriers to commercialization and garner executive level commitments to accelerate the commercialization and adoption of innovative solutions.

The success of this collaborative effort has sparked significant interest among the companies that participated and other members of the Green Chemistry & Commerce Council in applying this model to other technology areas where retailers and brands have a common need for new, green chemistry technologies or are seeking to address challenges in adoption of more sustainable options. Based on our experience, we have developed a set of criteria to choose technology targets appropriate for this type of collaborative intervention (as noted above) and are working on developing several models of collaborative supply chain innovation to accelerate the design and commercialization of other green chemistry technologies.

CRediT authorship contribution statement

Monica Becker: Conceptualization, Methodology, Writing - original draft, Project administration. **Joel A. Tickner:** Writing - review & editing, Supervision, Conceptualization, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

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