Identifying an Effective Defoamer for Certified Organic Maple Production

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There is currently strong market demand for certified organic maple syrup, and producers are paid a premium of between $0.10 and 0.20 per pound over the price of conventional syrup. While there are incentives and benefits for maple operations to become or remain certified, a significant challenge facing certified organic maple producers, and also discouraging producers from becoming certified, is the lack of an effective certified organic defoamer.

Foam development is inevitable in maple syrup production and requires the use of an agent or mechanism to prevent and control it. Uncontrolled foam can result in foam overflows, loss of product, syrup scorching and the development of off-flavors, as well as risks to personal safety and damage to evaporator pans. Because pure maple syrup is produced from maple sap with nothing added or removed except water, only minute quantities of defoamer should be used during the production process. In addition, too much defoamer can result in off-flavors or textures in syrup, or a greasy sensation on the tongue, lips, or palate.

The commercial conventional defoamers currently used in maple production meet this requirement well, and require only very small quantities to prevent or eliminate foam. Organic maple production requires that certified organic products be used as defoamers, and certified organic cooking oils (safflower, canola, sunflower, etc.) are the most common products currently used. However, because these products aren't specifically engineered to prevent, control, or reduce foam, they have relatively low efficacy (Garrett 2015, Martin 2017*a*,b). This results in increased difficulty in preventing or controlling foam compared to conventional defoamers, and increased incidences of foam overflows and other foam-related adverse events (Martin 2017*a*,b). In addition, their relatively low efficacy often requires that large quantities are used to control foam, which results in more frequent occurrences of defoamer off-flavors compared to syrup made with conventional defoamer.

The combination of potential crop losses from foam-related incidents, reductions in crop value due to off-flavors, and ultimately the many adverse effects of such a large proportion of organic syrup with off-flavors potentially being sold to consumers, underscore the need to identify or develop a certified organic defoamer for maple production that is both more effective at controlling foam than the culinary oils that are currently used, and which results in no off-flavors when used in the quantities necessary to adequately control foam. Thus, the overall objective of this project was to identify a certified organic defoamer that met these criteria.

Materials and Methods

To accomplish the overall objective a series of laboratory-level experiments with 35 °Brix concentrate were conducted to test the efficacy of 10 commercially-available certified organic defoaming agents and physical techniques to identify any products or mechanisms that were more effective at controlling foam than organic cooking oils, without perceptible or adverse impacts on flavor. In these experiments, one certified organic defoamer (Trans-O 580, Applied Material Solutions, WI, USA) exhibited substantially better efficacy than the control organic defoamer (organic sunflower oil, Emile Noël, Pont-Saint-Esprit, France), similar efficacy to that of the control conventional defoamer (Atmos 300K, Caravan Ingredients, KS, USA), and had no perceptible impacts on flavor (no defoamer or other flavor defects were noted). This product was selected for producer pilot-testing, and controlled experiments with commercial maple equipment.

To confirm whether the candidate defoamer was significantly more effective than current standard organic defoamers and produced no adverse impacts on flavor, controlled experiments with commercial-scale maple equipment were conducted in which syrup was produced simultaneously with the same batch of concentrate in two identical evaporators using the candidate and control organic defoamers, respectively. Specifically, two identical 3×10 evaporators (Model Deluxe, Les équipements d'érablière CDL, QC, Canada) in the University of Vermont Proctor Maple Research Center (UVM PMRC) Maple Processing Research Facility were set up identically, with the same burner and draft settings, liquid depth in pans, and draw-off temperatures. Evaporator settings were optimized for minimum foam develop-

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Automatic defoamer dispenser (probe not shown).

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ment. One evaporator was assigned to the Candidate defoamer (Trans-O-580), and the other to the Control defoamer (certified organic canola oil, Jedwards International, MA, USA) treatments.

During each trial of the experiment, 400-650 gallons of 22% sap concentrate was acquired from a nearby maple operation (Runamok Maple, Cambridge, VT) and divided equally into two stainless steel tanks which each supplied one of the evaporators. The evaporators were started simultaneously and run until the concentrate supply was fully consumed. Evaporator settings (draft, sap levels, draw-off temperature, etc.) were continuously monitored and adjusted as needed to ensure they operated as similarly to each other as possible. The syrup produced by each evaporator was collected in separate containers. Except for the first trial when the pans were sweetened, the collection of syrup for subsequent analyses began one hour after the start of processing, to ensure that the syrup represented the concentrate being processed that day and help minimize any carryover effects from material remaining in the evaporator. At the end of each trial, the syrup from each evaporator was filtered separately with a plate filter press and placed in a freezer until subsequent sensory analyses. The experiment was repeated four times during the 2019 production season: March 22, 27, 29, and April 3. Evaporators were drained, then cleaned with phosphoric acid following industry standard procedures between each experiment trial to further minimize potential carryover effects from defoamer residue on pans. The treatments were switched between the evaporators after the first two trials to further ensure any effects observed were due to the defoamer treatments, rather than any minute differences between the evaporators themselves.

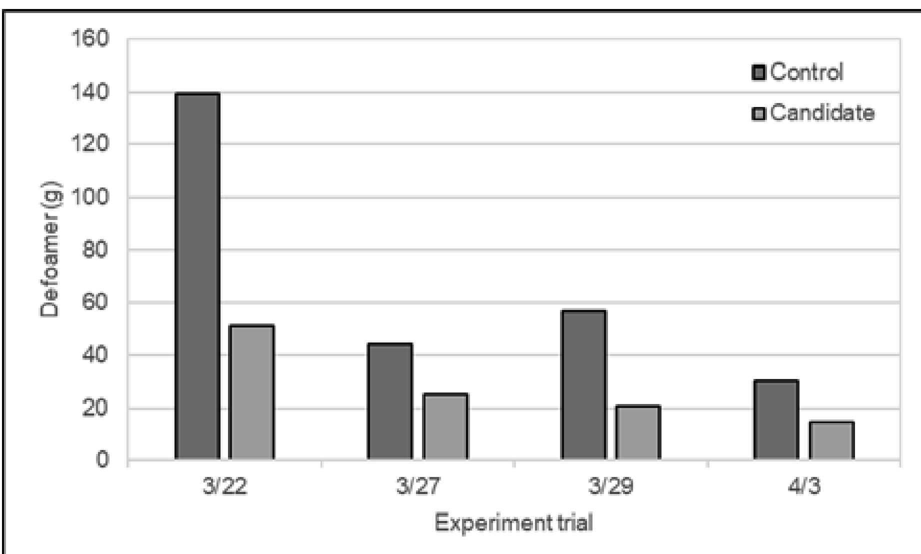

Figure 1. Quantity of Control and Candidate defoamer used (total for back and front pans) in evaporators processing the same pool of sap concentrate during four experiment trials in 2019.

Foam control and defoamer treatments

Each evaporator was equipped with a peristaltic pump-type automatic defoamer dispenser in identical locations and heights above the liquid in the back pan. These devices add a precise amount of defoamer at regular intervals through the unit's probe. In addition, if foam rises to the point where it touches the probe, the unit will add defoamer continuously until the foam subsides. During each experiment trial, the units were started with the same settings (rate and amount of defoamer added) in both evaporators, and then adjusted independently (higher or lower) as needed to control foam over the course of the trial. In the front pans, defoamer was added manually whenever foam reached a predetermined, marked height (7″ above the bottom of the pan). Three drops of defoamer were added initially; if foam was not controlled after one minute, three additional drops were added. If it was evident that it was possible to control the foam with fewer than three drops, fewer drops were used. The time, number, and location of each manual addition was noted. The defoamer containers for each treatment were weighed before and after each experiment trial to determine the total quantity of defoamer used in each evaporator. A paired, two-sided Student's *t*-test was used to determine whether significant differences existed in the quantity of defoamer used between the two treatments.

Flavor evaluation

Potential impacts of the Candidate defoamer on flavor were evaluated first with a standard sensory evaluation experiment to assess the frequency at which defoamer off-flavor or texture occurred in syrup produced with the

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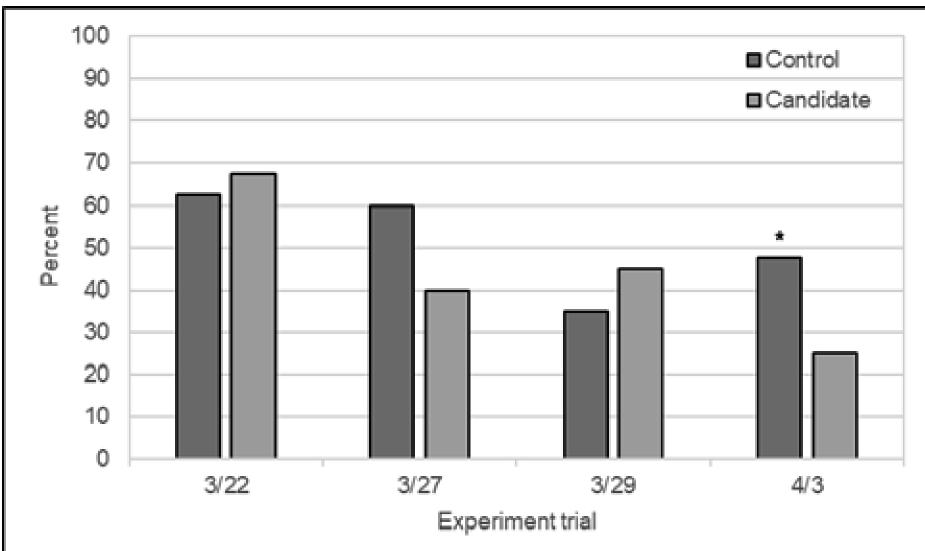

Figure 2. Percentage of "Yes" responses of sensory panelists to the question "Does this syrup have organic defoamer off-flavor (or texture)?" for each syrup produced simultaneously with the Control and Candidate defoamers in four experiment trials ($n = 40$ for each syrup). * indicates a statistically significant difference in the frequency of "Yes" responses between the syrups in the pair (McNemar's test, $p < 0.0389$).

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Candidate defoamer, and determine whether it was similar or less than the frequency in syrup produced simultaneously with the Control defoamer. (The general terms "defoamer off-flavor" or "defect" will be used henceforth to encompass both the flavor and textural aspects of this off-flavor).

An attribute difference test following standard sensory evaluation protocols and procedures (Meilgaard *et al.* 2006) was conducted with 40 healthy, adult panelists who were trained to identify defoamer off-flavor in maple syrup (either having completed the IMSI Grading School, or significant work training and experience assessing this attribute in maple syrup). Each pair of syrups produced simultaneously with the Control and Candidate defoamers during each trial was de-identified, given a random, 3-digit code, and presented to panelists in a balanced, randomized order to reduce presentation order bias and carryover effects.

Panelists were asked to taste each syrup in each pair and evaluate whether defoamer off-flavor was present (Yes or No), and then to indicate its level of defoamer off-flavor intensity using a verbally-anchored scale of defoamer off-flavor intensity, from "none" to "very strong." Results were compiled and McNemar's tests used to determine if significant differences existed in the frequency of "Yes" responses to the question of whether defoamer off-flavor was present between the pairs of syrup produced simultaneously with the Control and Candidate defoamers during each of the four trials.

To further investigate potential impacts of the Candidate defoamer on flavor, including the occurrence of defoamer off-flavor as well as defects of any other nature, the flavor of the syrup samples produced during the experiment trials was also assessed through sensory evaluation conducted by certified inspectors at ACER Division Inspection Inc. using the standard classification protocols and criteria used in the maple industry in Québec (http://ppaq.ca/en/producer/useful-information/classification/). Three certified inspectors evaluated each de-identified syrup sample and provided both individual and consensus assessments of each.

Results and Discussion

Foam control efficacy

Differences in the performance of the Control and Candidate defoamers were evident through several anecdotal observations made during the experiment trials. During the first experiment trial, foam overflowed from the back pan of the Control defoamer evaporator as the boiling point was initially reached; this did not occur in the Candidate defoamer evaporator (which reached the boiling point at the same time). The overflow in the Control defoamer evaporator was not controlled by the "emergency" addition of canola oil by the automatic defoamer dispenser, and only stopped when the evaporator was turned off.

For the remainder of the experiment trials, the Control defoamer evaporator had to be started on low fire until the boiling point was reached in order to avoid this type of overflow. This was not required with the Candidate defoamer evaporator; it could be started on high fire and reach the boiling point without any foam overflow. In addition, during all trials the automatic defoamer dispenser in the Candidate defoamer evaporator was able to be set at a lower rate to control foam in the back pan than that in the Control defoamer evaporator. And, although manual ad-

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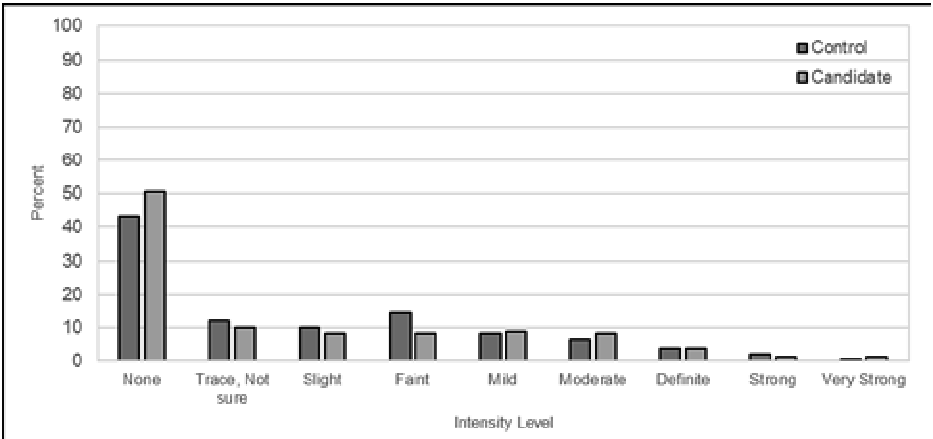

Figure 3. Overall average percentage of responses of sensory panelists for each level of the intensity scale to the question "Please indicate the intensity of organic defoamer off-flavor (or texture) of this maple syrup" for syrup produced simultaneously with the Control and Candidate defoamers in four experiment trials (n = 40).

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ditions of defoamer to the front pans were of similar frequency in the two evaporators, foam could be eliminated or controlled with fewer drops of the Candidate defoamer than of the Control defoamer.

The total quantity of defoamer used (back and front pans) in the two evaporators during each experiment trial is presented in Figure 1. An average of 45% less of the Candidate defoamer was used, although this difference was only marginally statistically significant ($p < 0.0992$). It should be noted that, in general, the usage rate for both defoamers was relatively high compared to that of conventional defoamers.

Flavor

The frequency of "Yes" responses of panelists to the question "Does this syrup have organic defoamer off-flavor?" for each syrup pair produced during the four experiment trials is presented in Figure 2. There were no significant differences in the frequency of "Yes" responses between pairs of syrup produced simultaneously with the Candidate and Control defoamers during any of the experiment trials except for that on April 3. For the pair produced during this trial, the syrup produced with the Candidate defoamer received significantly fewer "Yes" responses than the syrup produced with the Control defoamer (Figure 2). The results indicate that the Candidate defoamer does not result in a more frequent occurrence of defoamer off-flavor than the Control defoamer, and suggest that it could sometimes result in less frequent occurrences of this defect.

One notable aspect of the results of the sensory evaluation experiment is the relatively high frequency of "Yes"

responses for both types of syrup for some of the samples tested – for example, about 60% of the panelists indicated there was defoamer off-flavor present in the syrups produced with both the Control and Candidate defoamers during the trial on March 22 (Figure 2). This can be put into some context with the results of the second question asked in the sensory experiment, "Indicate the intensity level of organic defoamer off-flavor in this syrup." Figure 3 shows the average percentage of panelists' responses to this question in each category (None to Very strong) for the syrups produced with the Control and Candidate defoamers in the four experiment trials. The majority of responses for syrup produced with both treatments were low intensity, with averages of 88 and 86% of all responses being from None to Mild for syrup produced with the Control and Candidate defoamers, respectively (Figure 3).

The results of the sensory experiment likely reflect two limitations in its design. First, asking panelists to indicate if a specific off-flavor is present introduces a suggestion ("expectation error", Meilgaard *et al.* 2006), potentially introducing a bias toward detecting that defect and unconsciously predisposing panelists to perceive the flavor or respond "Yes." Second, providing panelists the means to subsequently indicate the intensity of the off-flavor they perceived could have increased the occurrence of panelists choosing "Yes" as the response to the first question when they were uncertain if the defect was present, because it allowed them to indicate subsequently that the flavor was present at a very low intensity (e.g. "Trace, Not sure", "Faint").

Despite these potentially mitigating factors, however, the results remain noteworthy and could still reflect a high frequency of defoamer off-flavor in syrup produced with organic defoamers in general. The limitations of this experimental approach to assess the potential impacts of the Candidate defoamer on syrup flavor were addressed with the second approach used to assess flavor, standard classification.

Table 1 presents the classification results for each syrup sample from the individual inspectors, as well as their consensus assessment. This method of assessing the flavor of the syrup samples produced in the experiment not only provides a means to mitigate the limitations of the sensory evaluation experiment, but also to address the question of whether there are any other potential impacts of the Candidate defoamer on syrup flavor besides characteristic defoamer off-flavor, as a defect in flavor of any type would be identified by the inspectors. A significant defoamer flavor defect would be indicated by a classification of "√R4." None of the syrup samples produced with either of the defoamers during the experiment trials was classified as √R4 (Table 1). Slight defects in flavor are indicated by a √, followed by a verbal description of the nature of the defect. For the syrup samples for which inspectors indicated the presence of a slight flavor defect with a √, defoamer was not the defect noted (Table 1). Thus, these results indicate that defoamer off-flavor was not present at any level, from slight to significant, in any syrup produced with either the Candidate or Control defoamers.

Conclusions

Taken together, the results of this study indicate that the Candidate de-

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foamer can be more effective at controlling foam with lower quantities than the organic cooking oils currently used as defoamers for certified organic maple production, and results in a similar or lower frequency of defoamer off-flavor, and no other apparent significant general impacts on flavor. Although it still presents many of the same issues as other organic defoamers (high usage quantities and increased risks of flavor defects), because of its effectiveness at controlling foam, particularly in the back pan, this product could provide an alternative option for foam control in some organic maple operations.

Producer Pilot-testing and General Notes

Four operations pilot-tested the Candidate defoamer during the 2019 maple production season, two with dripper-style defoamer dispensers, and two with peristaltic pump-type automatic dispensers. The operations with automatic dispensers indicated the Candidate defoamer was very effective and reported they were very to extremely likely to use the product in forthcoming seasons. Both indicated there was a significant (or complete) reduction in foam overflows upon initial boiling. The two operations with dripper-style dispensers reported difficulty adjusting the dispensing rate to the appropriate level with the Candidate defoamer (it was either too fast or too slow). One of these operations reverted to using organic safflower oil because of this, even though they felt that the Candidate defoamer seemed to be more effective at controlling foam. All three of the remaining operations reported using less of the Candidate defoamer than the typical product used in their operations (from ~25-50% less). Of note, however, with sap of very poor quality all operations reported similar difficulty controlling foam with the Candidate defoamer as compared to organic canola or safflower oil.

This defoamer has some specific storage and handling instructions, including that it should not be exposed to freezing temperatures, and needs to be mixed well before each use. More information can be found in the technical bulletin for Trans-O-580, which can be obtained from the manufacturer (www.appliedmaterialsolutions.com), or from maple equipment dealers who sell the product. The product is currently certified organic only in the United States.

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		Inspector 1		Inspector 2		Inspector 3		Concensus	
Defoamer Treatment	Experiment Trial	Grading	Comments	Grading	Comments	Grading	Comments	Grading	Comments
Control	3/22	OK		√	Lightly wood	√		√	Lightly wood
Candidate	3/22	√	Sap. Caramelized	OK		√	Wood	√	
Control	3/27	√	Caramelized	OK		OK		OK	
Candidate	3/27	OK		OK		√	Wood	OK	
Control	3/29	OK		OK		OK		OK	
Candidate	3/29	OK		OK		OK		OK	
Control	4/3	√		OK		OK		OK	
Candidate	4/3	OK		OK		√		OK	

Table 1. Consensual and individual sensory quality grading by three certified inspectors at ACER Division Inspection Inc. of each syrup sample produced simultaneously with the Control and Candidate defoamers in four experiment trials. "√" indicates a slight trace of a flavor defect, and "OK" indicates a syrup free of flavor defects. ("Wood" flavor is often referred to as "metabolism" in English).

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Like any product used in organic maple production, the certifying agent for an operation must be notified and approve of its use. Likewise, it is also advisable for bulk producers to notify buyers of the type of defoamer used.

Best Practices

Most engineered organic defoamers like the one tested in this study are also based on organic cooking oils, and as such are sensitive to degradation like their culinary counterparts. In addition, they are unquestionably not as effective at controlling foam as conventional defoamers. Thus, it is particularly important for certified organic maple operations to follow best practices for defoamer use and care, and for controlling and minimizing foam development during processing. The following apply to all defoamers, both organic and conventional.

Heat, oxygen, and light all degrade defoamers and cause rancidity that can impart rancid off-flavor to syrup (Martin 2011, 2016). All defoamers should be stored away from heat, and material in dispensers replaced frequently, as the heat from the evaporator rapidly degrades the defoamer within them. Use new defoamer each season (do not store and reuse last year's supply). Dispensers should be thoroughly cleaned periodically (or replaced when necessary) to remove residues, which can impart a rancid flavor to fresh defoamer.

The amount of foam generated typically increases with the amount of heat, the accumulation of niter on pans, and reductions in sap quality. Any practices to mitigate these factors will help minimize foam development and the amount of defoamer required to control excessive foaming. Maintaining heat settings of the evaporator at levels as low as possible to balance desired production rates, and rigorous attention to managing niter formation (e.g. reversing flow or changing pans frequently) are primary means to achieve this. If using organic cooking oil, starting on low fire until the initial boiling point is reached can be an approach to reduce the foam overflows that occur frequently at this stage of processing.

The overall goal is to use the minimum amount of defoamer possible. A variety of devices are available to dispense defoamer at a constant rate, or as needed when foam reaches a certain level, including cups, dripper-style dispensers, and automatic peristaltic pump-based dispensers. Any of these will add more defoamer than necessary if not used and monitored closely. Ensuring that as little defoamer as possible is being added at all times, whichever device or method of addition is used, requires regular and rigorous attention. Peristaltic pump-type automatic defoamers work particularly well with organic defoamers (which are liquid at room temperature) and can reduce the amount of defoamer used if operated properly. For manual additions of defoamer, note that spray bottles add significantly more defoamer than dropper bottles. Note also that additions of defoamer to the front pan are generally more likely to result in defoamer flavor defects than additions to the back pan, with the likelihood increasing with proximity of the addition to the draw-off (Martin 2016, 2017c).

Acknowledgements

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