Research: RO and flavor

Assessment of the Flavor of Syrup Produced with High-Brix RO Systems

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Concentrating sap with reverse osmosis (RO) substantially increases the efficiency and profitability of processing maple sap into syrup by reducing the amount of fuel and time required to complete concentration to syrup density in the evaporator, with gains proportional to the level of sap pre-concentration (Figure 1, van den Berg *et al.* 2011). Because most flavor development in maple syrup occurs through nonenzymatic browning reactions as sap is processed with heat in the evaporator, it has often been speculated that reduced evaporator processing time resulting from the use of RO might also result in perceptible impacts on syrup flavor. However, a series of controlled experiments conducted at the University of Vermont Proctor Maple Research Center using the same sap processed to different levels with RO determined that concentrating sap up to 21.5% prior to boiling in standard maple evaporators had no substantive effects on syrup composition or flavor (van den Berg *et al.* 2011, 2012, 2014, and 2015). For example, syrup produced simultaneously from raw sap and the same sap that had been concentrated to 8% with RO contained similar quantities of flavor compounds, and the flavor of the syrup was indistinguishable by panelists in sensory evaluation experiments (van den Berg *et al.* 2014). The same results were observed in syrup produced simultaneously with the same sap concentrated to 8 and 21.5% (van den Berg *et al.* 2012).

RO systems capable of concentrating maple sap to 30-40% (hereafter referred to as "High-Brix") have recently been developed, and could provide substan-

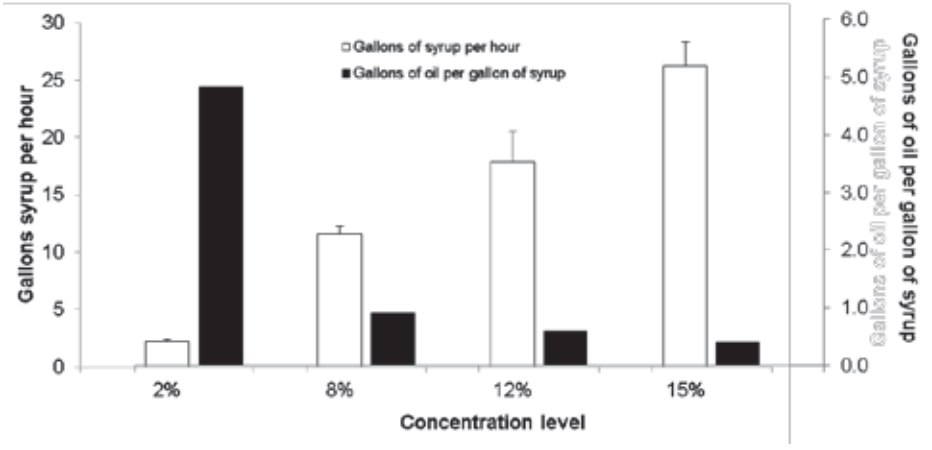

Figure 1. Rate of syrup production per hour and fuel consumed per gallon of syrup produced in 3 x 10' oil-fueled evaporators processing sap at 4 different concentrations of starting sap material: 2, 8, 12, and 15%.

tial additional gains in processing and time efficiency. However, the greater level of sap pre-concentration and resulting reductions in thermal processing time resurrect questions about potential impacts on the syrup produced, particularly with respect to flavor. Thus, the overall objective of this study was to determine if the production of syrup with High-Brix systems significantly impacts syrup flavor. Since previous controlled experiments found no substantive effects on syrup flavor with sap pre-concentration up to 21.5%, sensory experiments with syrup produced by High-Brix systems were chosen as a first step to address the question of potential impacts of these systems on syrup flavor. The most essential information to determine initially was whether the flavor of syrup produced with these systems is appealing and liked, and characteristic of the flavor of pure maple syrup. Sensory experiments were conducted to address these questions and thus assess the potential impacts of producing syrup with High-Brix systems.

Materials and Methods

Syrup samples were obtained from six producers that used High-Brix Systems (Lapierre Equipment "Hyper-Brix" or H2O Innovation "Super-Concentrator") during the 2016 production season. Each producer was asked to provide samples that represented the early, middle, and late portions of their production season. Once obtained, the color of each sample was measured as percent light transmittance at 560nm with a spectrophotometer (Thermo-Fisher Spectronic Genesys 8), and density with a digital refractometer (Misco Palm Abbe PA202). Other pertinent information about each sample, including production date, location, and

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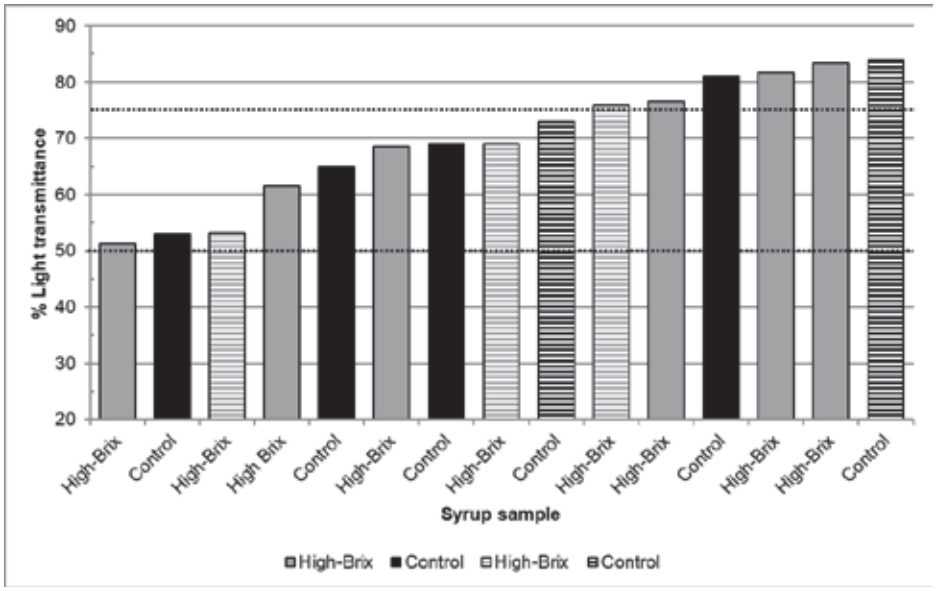

Figure 2. Light transmittance and production type of syrup samples evaluated in sensory experiments. Dotted lines demarcate the light transmittance values for syrup grades (≥75% = Golden Delicate, 50% - 74.9% = Amber Rich). Solid bars indicate syrup produced in certified organic operations, and striped bars indicate conventionally-produced syrup.

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whether it was produced in a certified organic or conventional operation, was also recorded. Nine of these samples were selected for sensory experiments. Once selected, a set of syrup samples with a similar range of color and production type (organic or conventional) that were produced with standard RO systems (e.g. 25% or lower) during the 2016 season were obtained (Figure 2). Syrup produced with other processing technologies that could potentially impact flavor, such as air injection, were excluded. All samples were screened for flavor defects and appropriate density prior to sensory experiments.

Sensory experiments were conducted to assess the overall acceptance or "liking" of syrup produced with High-Brix systems, as well as whether the flavor of High-Brix syrup was perceived as being characteristic of pure maple syrup. All sensory experiment procedures, design, and analyses were conducted following standard methodology for acceptance and affective testing as described by Meilgaard et al. (2006) and Lawless and Heymann (2010). For these experiments, each of the nine High-Brix and six Control samples was assigned a random, 3-digit code. Forty-six healthy, non-smokers who liked pure maple syrup were recruited and participated in the experiments in one of four sessions (Table 1). Each panelist was presented all 15 samples in randomized order in opaque containers to eliminate the potential influence of syrup color on flavor perception. Panelists were instructed to taste each sample and answer the following two questions about their perception of the syrup's overall flavor:

1) How much do you like or dislike the overall flavor of this syrup? Panelists were asked to choose a response from a nine-point verbally-anchored hedonic scale, from "Dislike extremely" to "Like extremely"; and

2) Is the flavor of this syrup characteristic of pure maple syrup? Panelists were asked to choose a response from a seven-point verbally-anchored Likert agreement scale, from "Entirely disagree" to "Entirely agree".

Panelists were instructed to cleanse their palates with water between each sample, and an extended rest period (3-5 minutes) was taken after every five samples to reduce sensory fatigue.

For each question, the average frequency of each response (e.g. "like extremely", "dislike "moderately", etc. for Question 1, and "entirely agree", "disagree slightly", etc. for Question 2) was calculated across all 46 panelists for each syrup sample. Paired Student's *t*-tests were used to determine if significant statistical differences existed in the frequency of individual responses for High-Brix and Control samples.

	No. of Panelists	Age		
		Mean	Min.	Max.
Female	14	53	39	70
Male	32	50	21	80
Overall	46	51	21	80

Table 1. Age and gender distributions of sensory experiment panelists.

Results and Discussion

The High-Brix syrup samples evaluated ranged in light transmittance from 51.4-83.3% (Figure 2). Four samples were Golden Delicate grade, and five were Amber Rich; six were produced in certified organic operations, and three in conventional operations. The color,

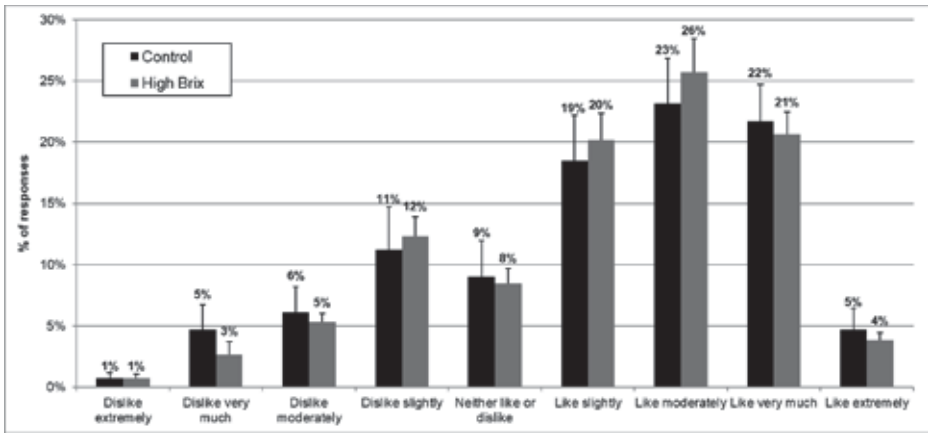

Figure 3. Average frequency of responses of 46 panelists for High-Brix (n=9) and Control (n=6) syrup samples for each category on a 9-point verbally-anchored hedonic scale to the question, "How much do you like or dislike the overall flavor of this syrup?" Error bars represent the standard error of the mean.

grade, and processing type of Control samples were similarly distributed (Figure 2).

The average frequencies of panelists' responses to each sensory question for High-Brix and Control samples are presented in Figures 3 and 4. Panelists' responses to the question "How much do you like or dislike the overall flavor of this syrup" were very similar for High-Brix and Control samples (Figure 3). Overall, 70% of the average responses for High-Brix syrup and 68% of those for Control syrup were "liked" to some degree, from "slightly" to "extremely" (Figure 3). Likewise, there was no significant difference ($p < 0.9453$) in the frequency of each response between the

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	Sample ID	Dislike extremely	Dislike very much	Dislike mod.	Dislike slightly	Neither like or dislike	Like slightly	Like mod.	Like very much	Like extremely	Minimum	Maximum
Control	151	0%	2%	2%	2%	4%	11%	35%	35%	9%	Dislike very much	Like extremely
	268	2%	2%	4%	17%	11%	11%	28%	22%	2%	Dislike extremely	Like extremely
	440	0%	2%	4%	7%	4%	28%	28%	22%	4%	Dislike very much	Like extremely
	577	0%	0%	2%	2%	11%	30%	22%	22%	11%	Dislike moderately	Like extremely
	902	0%	9%	15%	22%	2%	20%	13%	17%	2%	Dislike very much	Like extremely
	953	2%	13%	9%	17%	22%	11%	13%	13%	0%	Dislike extremely	Like extremely
High Brix	172	0%	0%	7%	11%	15%	20%	33%	15%	0%	Dislike moderately	Like extremely
	213	2%	0%	4%	13%	9%	22%	17%	30%	2%	Dislike extremely	Like extremely
	227	0%	4%	4%	7%	11%	13%	35%	22%	4%	Dislike very much	Like extremely
	264	0%	0%	2%	15%	2%	24%	28%	24%	4%	Dislike moderately	Like extremely
	267	2%	0%	4%	13%	11%	15%	33%	17%	4%	Dislike extremely	Like extremely
	412	0%	2%	9%	15%	9%	22%	28%	11%	4%	Dislike very much	Like extremely
	550	0%	7%	4%	9%	7%	20%	28%	22%	4%	Dislike very much	Like extremely
	668	0%	2%	5%	7%	7%	34%	18%	23%	5%	Dislike very much	Like extremely
	861	2%	9%	9%	22%	7%	13%	11%	22%	7%	Dislike extremely	Like extremely

Table 2. Frequency, minimum, and maximum responses of 46 panelists for each of nine High-Brix and 6 six Control syrup samples for each category on a 9-point verbally-anchored hedonic scale to the question "How much do you like or dislike the overall flavor of this syrup?"

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two types of syrup – the average percentage of individual responses (e.g. "like extremely", "dislike slightly", etc.) did not differ between High-Brix and Control syrup (Figure 3).

Table 2 presents the frequency of responses for each individual syrup sample, and further illustrates that the acceptance of syrup flavor was very similar between High-Brix and Control syrup. These results indicate that the flavor of High-Brix syrup was generally liked by panelists and was liked similarly to syrup of similar color produced with standard RO systems.

Panelists' responses to the question "Is the flavor of this syrup characteristic of pure maple syrup" were also very similar for High-Brix and Control samples (Figure 4). For High-Brix samples, an average of 72% of responses were some level of agreement with this statement, from "slightly" to "entirely," and 73% for Control samples (Figure 4). Likewise, there was no significant difference ($p < 0.9375$) in the frequency of individual responses between the two types of syrup – the frequency of responses "agree entirely," "disagree slightly," etc. did not differ between High-Brix and Control syrup samples (Figure 4). These results indicate that panelists generally agreed that High-Brix syrup had flavor that was characteristic of pure maple syrup.

Together, these results indicate that syrup produced with High-Brix systems has flavor that is generally appealing and liked, and is characteristic of pure maple syrup. While these results do not provide an indication of whether the use of High-Brix systems results in *any* impacts on flavor, they do suggest that the production of syrup with High-Brix systems doesn't generally result in significant or adverse impacts on syrup flavor. As with all processing equipment, proper use of High-Brix systems according to the manufacturer's instructions is essential to ensuring

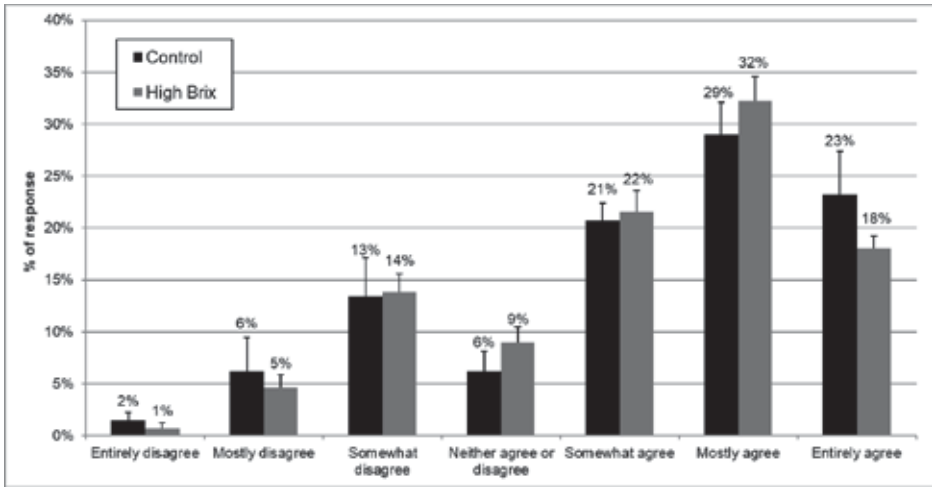

Figure 4. Average frequency of responses of 46 panelists for High-Brix (*n=9*) and Control (*n=6*) syrup samples for each category on a 7-point verbally-anchored Likert agreement scale to the question, "Is the flavor of this syrup characteristic of pure maple syrup?" Error bars represent the standard error of the mean.

optimal quality and flavor.

The range in responses for each sample to the question "How much do you like or dislike the overall flavor of this syrup" is important to note (Table 2). Each sample had at least one panelist indicate the highest or second-highest level of dislike, as well as the highest level of liking. This highlights the fact that the perception and appeal of syrup flavor is highly subjective, and varies considerably between individuals. The definition of "good syrup flavor" is unique to each person, and this is an important factor to consider when discussing and evaluating syrup flavor or the potential impacts of processing technologies on syrup flavor.

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