

From 8 to 35 °Brix: Research on reverse osmosis and syrup flavor and quality



Photo: Brian Stowe

Abby van den Berg, Ph.D.
Research Associate Professor
University of Vermont
Proctor Maple
Research Center

Reverse Osmosis/Membrane Separation

Increases efficiency
through reductions in
boiling time and fuel
costs

Other effects?
Chemical composition?
Flavor?



Experiments

Controlled experiments conducted with commercial maple equipment at UVM PMRC Maple Processing Research Facility to investigate impacts of RO on syrup composition and flavor:

Raw sap vs. 8% Concentrate

2, 8, 12, and 15%

8% vs. 22% Concentrate



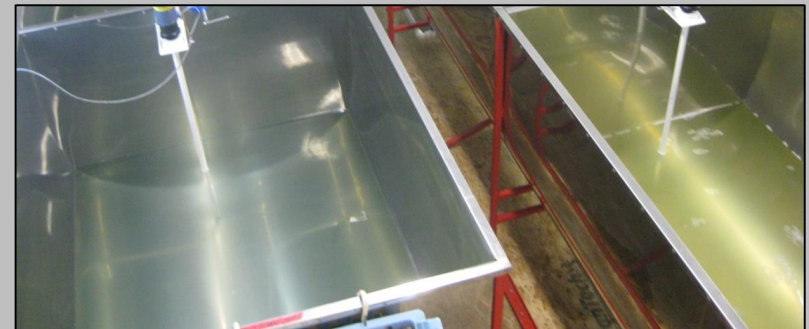
Maple Processing Research Facility (MPRF) at UVM PMRC

First Experiment Objective

Investigate the effects of pre-concentrating sap with RO on:

Syrup composition, properties, flavor

Does syrup produced from raw sap differ from syrup produced with the same sap concentrated by RO?



van den Berg, A.K., Perkins, T.D., Isselhardt, M.L., Godshall, M.A. and Lloyd, S.W. 2014. Effects of membrane separation on maple syrup composition and flavor. *International Sugar Journal* 116:656-665.

Experiment Methods

Produce syrup
from raw sap and
same sap
concentrated to 8%

Compare
composition and
flavor



Experiment Methods

2 Treatments:

Raw sap (2%) and
same sap
concentrated to 8%



Experiment Methods



Each tank fed one of two evaporators

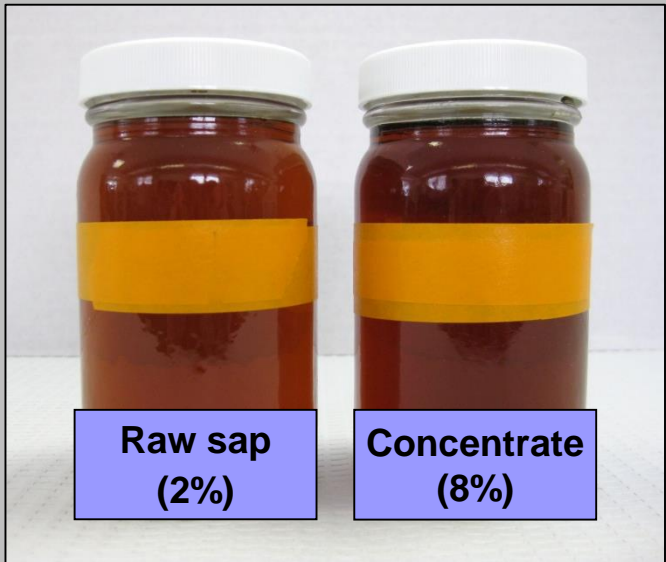
Experiment Methods



Syrup from each evaporator collected and filtered separately

Experiment Methods

Packed for analysis



Repeated on 6 days during production season

Syrup analyses

Composition and properties:

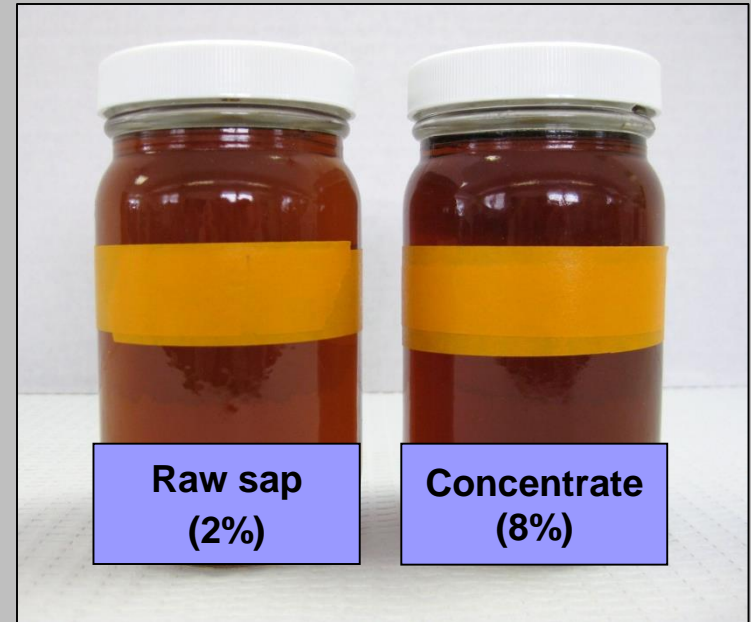
Color, pH, conductivity

Inorganic Minerals

Flavor:

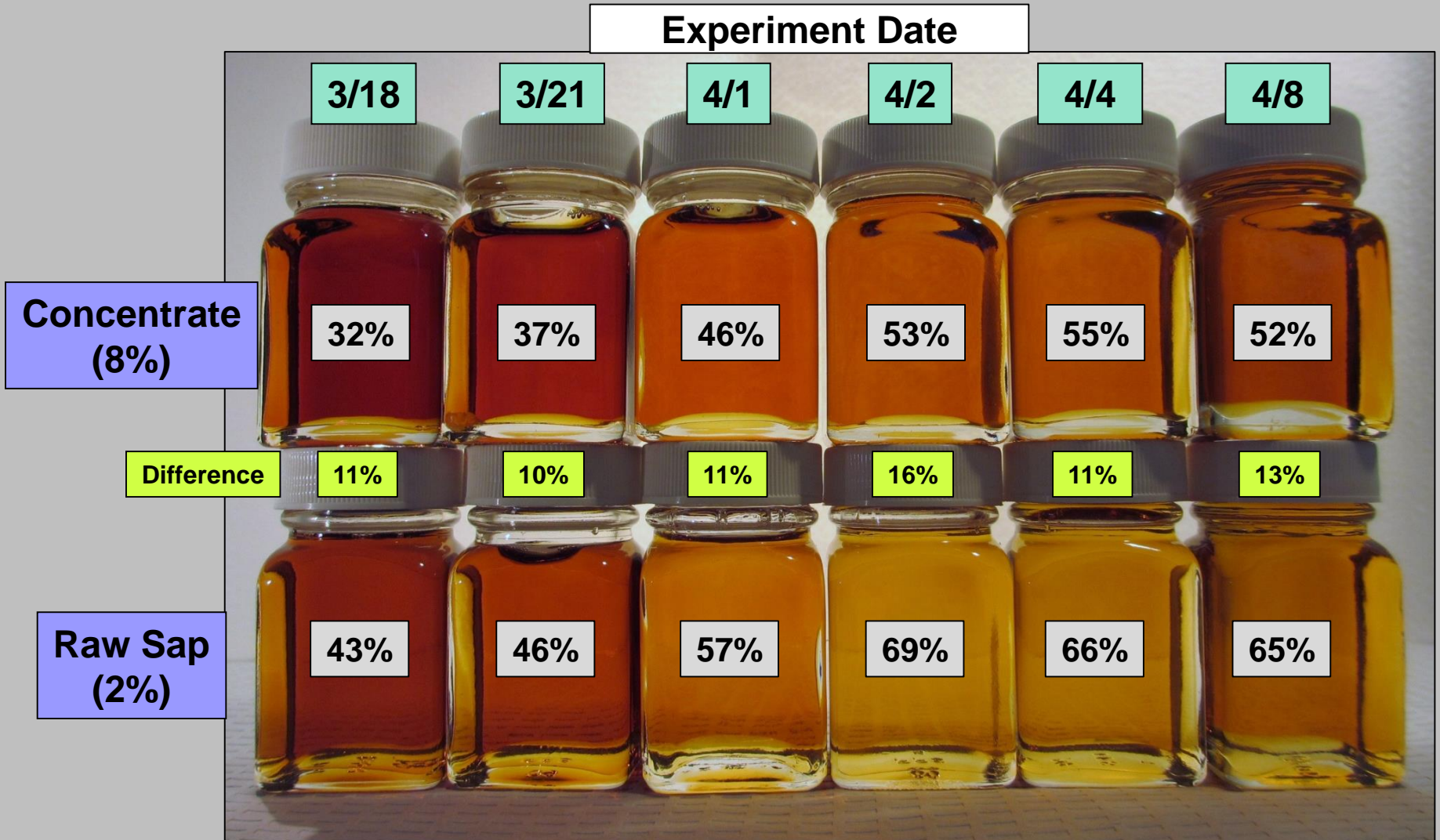
Volatile flavor
compounds

Sensory evaluation



**Does attribute differ in
syrup produced with
raw sap and same sap
concentrated with RO?**

Results: Syrup color



Results: Syrup properties and composition

Parameter measured	Raw Sap (2%)	Concentrated Sap (8%)	<i>p</i> -value
Brix (°)	67.1 ± 0.2	67.2 ± 0.1	0.4142
Conductivity (μS cm ⁻¹)	171.6 ± 11.5	162.9 ± 9.1	0.1572
Light transmittance (%)	57.7 ± 4.4	45.9 ± 3.8	0.0001
pH	7.1 ± 0.05	7.5 ± 0.09	0.0091
Calcium (ppm)	946 ± 77	939 ± 23	0.9164
Phosphorous (ppm)	2.3 ± 0.7	4.1 ± 1.2	0.1424
Potassium (ppm)	1948 ± 37	2009 ± 48	0.2694
Magnesium (ppm)	153.2 ± 7.7	133.1 ± 8.4	0.0063
Iron (ppm)	1.9 ± 0.5	1.9 ± 0.6	0.9171
Manganese (ppm)	27.2 ± 5.1	16.0 ± 2.4	0.1097
Boron (ppm)	1.2 ± 0.2	0.9 ± 0.1	0.0625
Copper (ppm)	0.9 ± 0.1	1.0 ± 0.1	0.6274
Zinc (ppm)	3.2 ± 0.1	3.6 ± 0.2	0.1084
Sulfur (ppm)	17.5 ± 1.2	18.7 ± 1.2	0.5443
Sucrose (%)	65.4 ± 0.9	64.2 ± 0.7	0.2175
Glucose (%)	0.11 ± 0.004	0.09 ± 0.006	0.0125
Fructose (%)	0.69 ± 0.02	0.67 ± 0.02	0.4607
Total invert sugar (%)	0.79 ± 0.02	0.75 ± 0.02	0.0938
Volatile flavor compounds (millions of peak area count)	2.4 ± 0.3	2.3 ± 0.3	0.9166

Average composition and properties of syrup produced with raw sap and the same sap concentrated to 8%. *p* value for paired Student's *t*-test (n=6).

Results: Sap, Concentrate and Permeate

Experiment trial date	3/18/2011			3/21/2011			4/1/2011			4/4/2011			4/8/2011		
Material type	P	S	C	P	S	C	P	S	C	P	S	C	P	S	C
Brix (°)	0.0	2.3	8.4	0.0	2.4	7.7	0.0	2.4	8.1	0.0	2.5	8.2	0.0	2.2	8.0
pH	6.3	7.5	7.7	5.8	6.7	7.1	6.0	7.0	7.3	6.0	7.0	7.4	6.0	6.7	7.1
Conductivity ($\mu\text{S cm}^{-1}$)	6.3	460.7	1218.0	6.5	504.7	1217.0	3.2	398.0	987.8	3.3	456.6	1105.0	4.6	464.5	1203.0
Calcium (ppm)	0.09	49.9	196.0	0.12	60.0	198.0	0.04	41.8	141.0	0.11	50.5	173.0	0.11	52.1	193.0
Phosphorous (ppm)	bdl	0.5	3.4	bdl	0.5	2.2	bdl	0.4	1.9	bdl	0.2	1.1	bdl	0.3	1.4
Potassium (ppm)	1.1	58.8	256.0	1.0	62.8	257.0	0.5	49.9	212.0	0.5	56.1	202.0	0.7	56.7	276.0
Magnesium (ppm)	0.012	5.6	20.5	0.013	6.7	20.5	0.004	4.5	14.5	0.009	5.7	18.1	0.010	6.0	20.6
Iron (ppm)	bdl	0.1	0.2	bdl	0.1	0.2	bdl	0.0	0.1	bdl	0.1	0.1	bdl	0.1	0.2
Manganese (ppm)	bdl	5.5	22.0	bdl	5.6	18.6	bdl	4.2	14.3	bdl	5.3	17.9	bdl	6.0	21.8
Boron (ppm)	bdl	0.1	0.1	bdl	0.1	0.1	bdl	0.0	0.1	bdl	0.1	0.1	bdl	0.0	0.1
Copper (ppm)	bdl	0.1	0.2	bdl	0.1	0.2	bdl	0.0	0.2	bdl	0.0	0.2	0.03	0.0	0.1
Zinc (ppm)	bdl	0.3	1.2	bdl	0.3	1.0	bdl	0.2	0.8	bdl	0.2	1.0	bdl	0.3	1.0
Sulfur (ppm)	bdl	0.8	3.7	bdl	1.0	3.9	bdl	0.7	2.5	bdl	0.9	3.5	bdl	1.0	4.0
Sucrose (%)	nm	1.8	7.1	nm	1.8	6.1	nm	2.0	7.0	nm	1.9	6.4	nm	1.6	6.4
Glucose (%)	nm	0.07	0.24	nm	0.09	0.25	nm	0.07	0.22	nm	0.10	0.26	nm	0.09	0.23
Fructose (%)	nm	0.04	0.12	nm	0.04	0.14	nm	0.03	0.11	nm	0.04	0.13	nm	0.04	0.13
Total invert sugar (%)	nm	0.1	0.4	nm	0.1	0.4	nm	0.1	0.3	nm	0.1	0.4	nm	0.1	0.4

Composition of raw sap, 8% concentrate, and permeate for 5 experiment trials.

Results: Sap, Concentrate and Permeate

	Permeate	Sap	Concentrate	Calculated Concentration
Brix (°)	0.0	2.4	8.1	8.1
Calcium (mg kg ⁻¹)	0.04	41.8	141.0	141.0
Phosphorous (mg kg ⁻¹)	bdl	0.4	1.9	1.3
Potassium (mg kg ⁻¹)	0.5	49.9	212.0	168.3
Magnesium (mg kg ⁻¹)	0.004	4.5	14.5	15.0
Iron (mg kg ⁻¹)	bdl	0.04	0.12	0.14
Manganese (mg kg ⁻¹)	bdl	4.2	14.3	14.2
Boron (mg kg ⁻¹)	bdl	0.04	0.09	0.14
Copper (mg kg ⁻¹)	bdl	0.04	0.15	0.14
Zinc (mg kg ⁻¹)	bdl	0.2	0.8	0.7
Sulfur (mg kg ⁻¹)	bdl	0.7	2.5	2.3
Sucrose (%)	nm	2.0	7.0	6.6
Glucose (%)	nm	0.07	0.22	0.24
Fructose (%)	nm	0.03	0.11	0.10
Total invert sugar (%)	nm	0.10	0.33	0.34

Composition of raw sap, the same sap concentrated to 8%, and the calculated composition of the concentrate based on the concentration factor (3.4x)

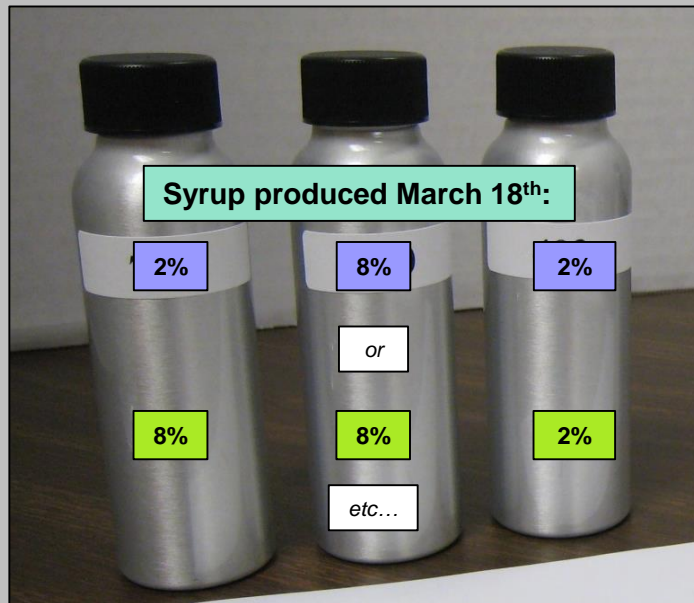
Results: Syrup flavor

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Volatile flavor compounds (millions of peak area count)	2.4 ± 0.3	2.3 ± 0.3	0.9166

Syrup flavor: Sensory evaluation

Triangle Test:

Is there an overall difference in flavor between 2 samples?



Syrup flavor: Sensory evaluation



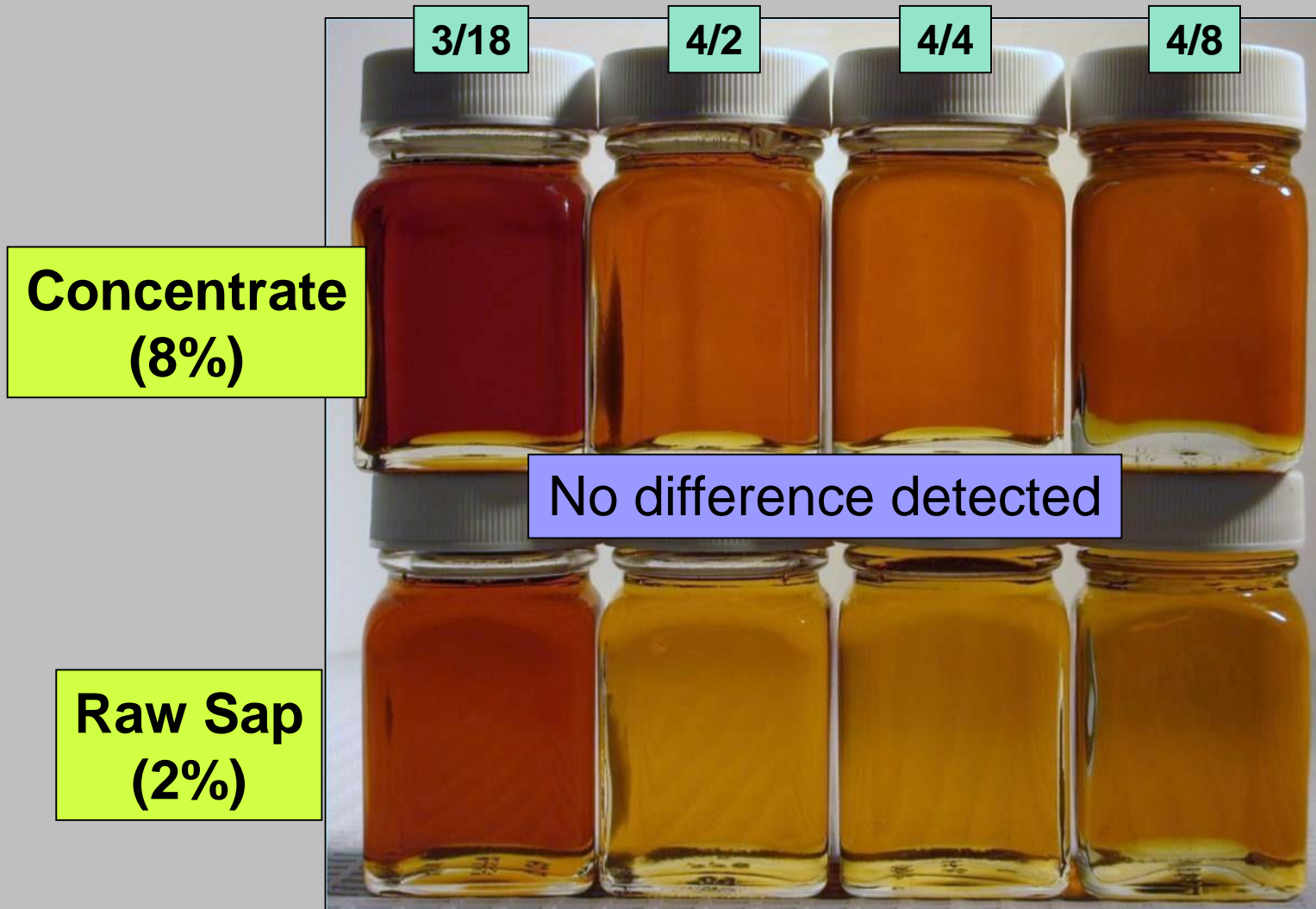
Triangle Tests

4 Syrup pairs
3/18, 4/2, 4/4, 4/8



Is there a difference in flavor between syrup made simultaneously from raw sap and concentrate?

Syrup flavor: Sensory evaluation



Additional experiments: Higher and varied concentration levels

Experiments to
examine:
2, 8, 12, and 15%

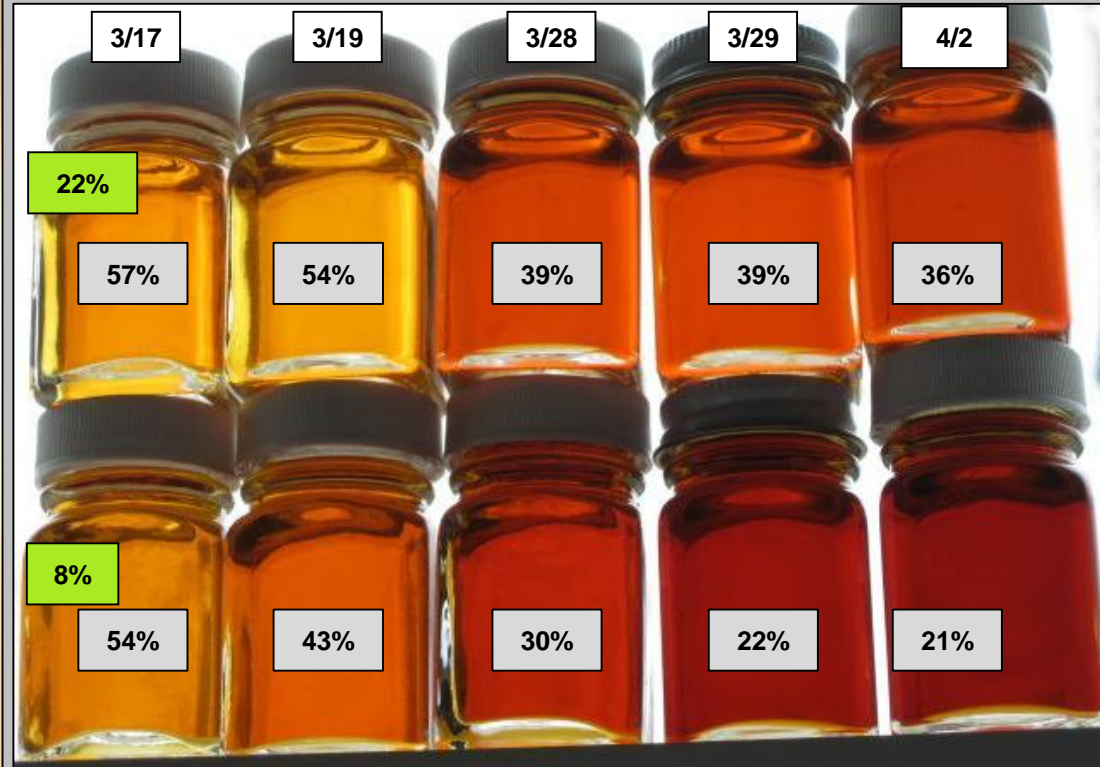
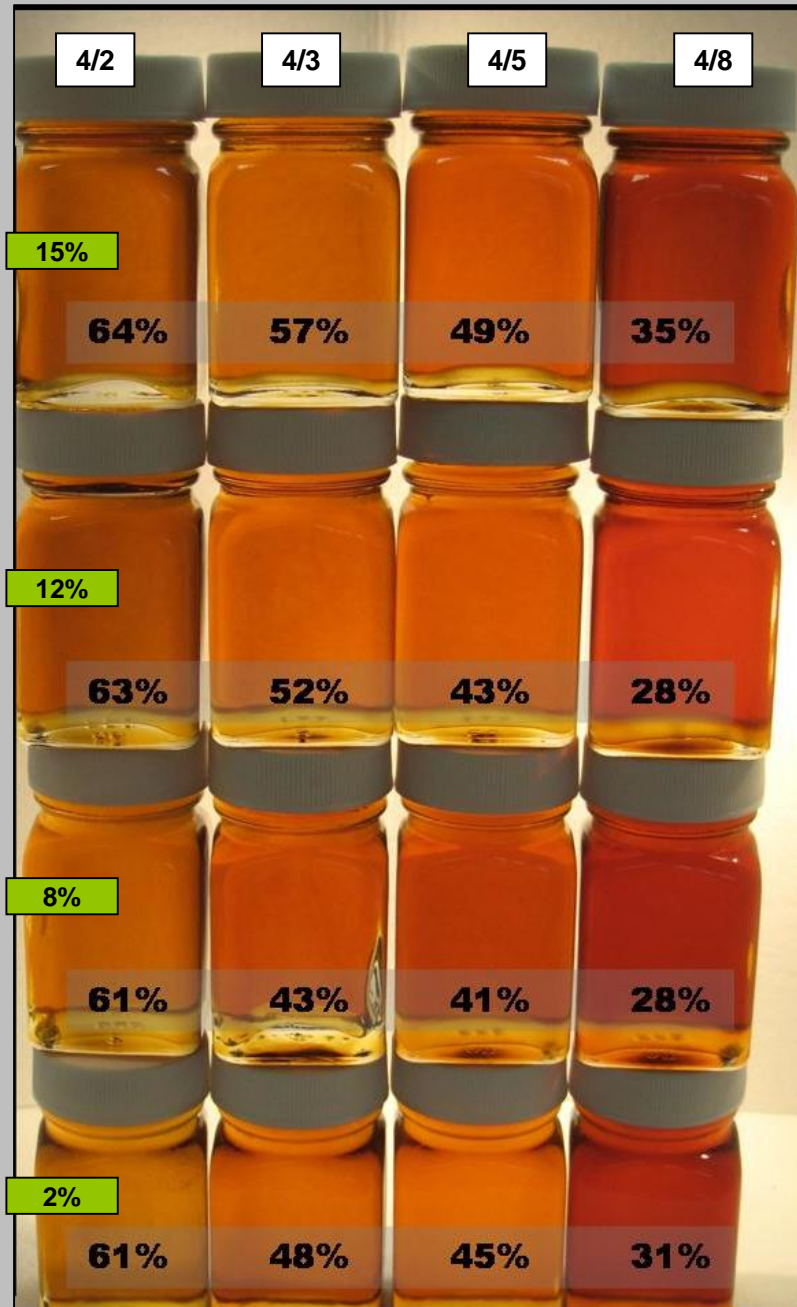
8% vs. 22%
Concentrate

Similar
methodology

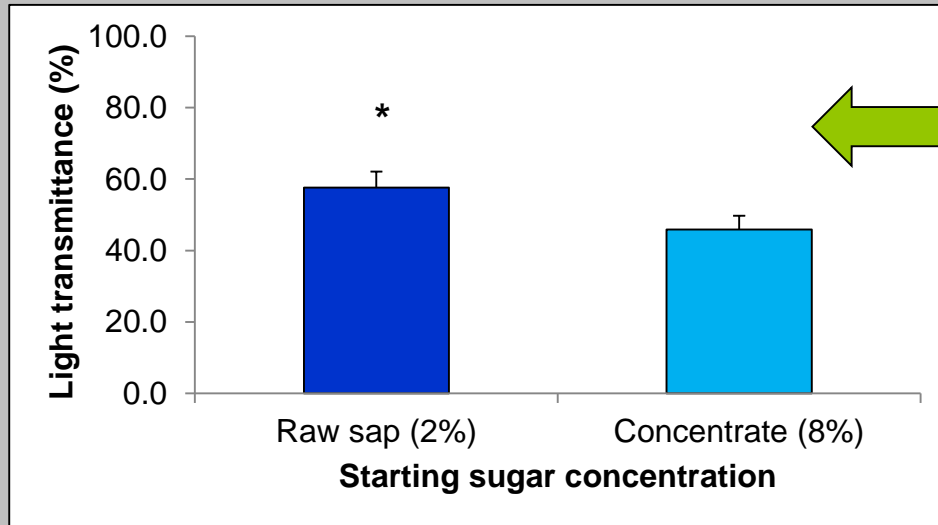


van den Berg, A.K., Perkins, T.D., Isselhardt, M.L., Godshall, M.A. and Lloyd, S.W. 2012. Maple syrup production with sap concentrated to high levels by membrane separation: effects on syrup chemical composition and flavor. *International Sugar Journal* 114:572-576.
van den Berg, A.K., Perkins, T.D., Isselhardt, M.L., Godshall, M.A. and Lloyd, S.W. 2011. Effects of producing maple syrup from concentrated and reconstituted sap of different sugar concentrations. *International Sugar Journal* 113:35-44.

Results: Syrup Color

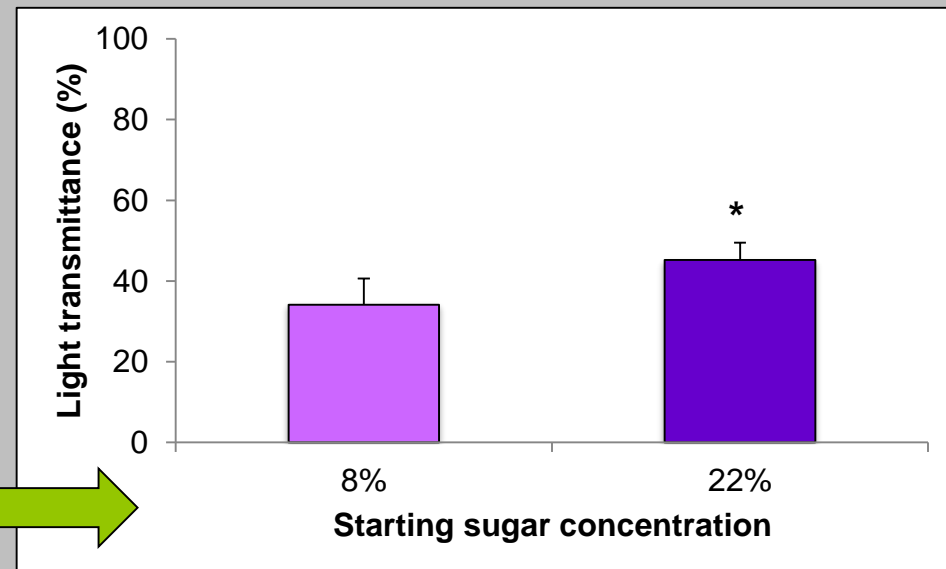


RO effects on syrup color?



Syrup made from raw sap tends to be **lighter** than syrup made with sap concentrated to 8%

Once RO is used:
Syrup made with more concentrated sap tends to be **lighter** than syrup made from less concentrated sap



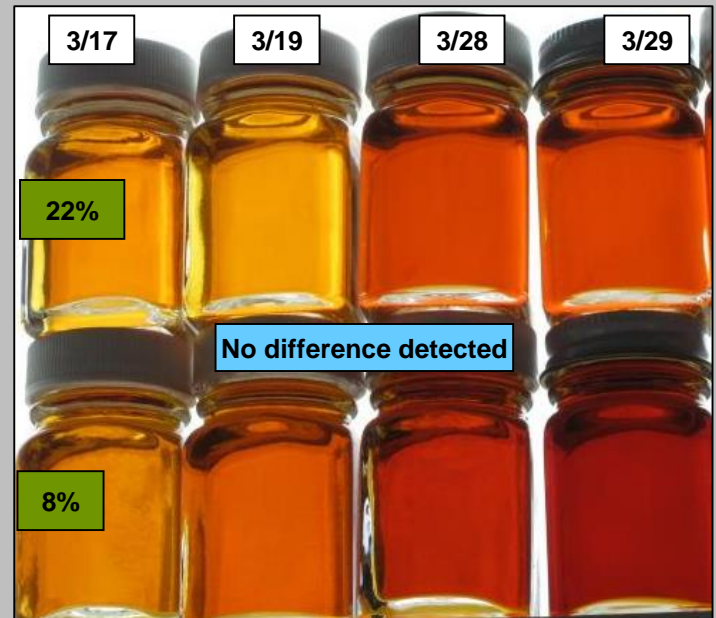
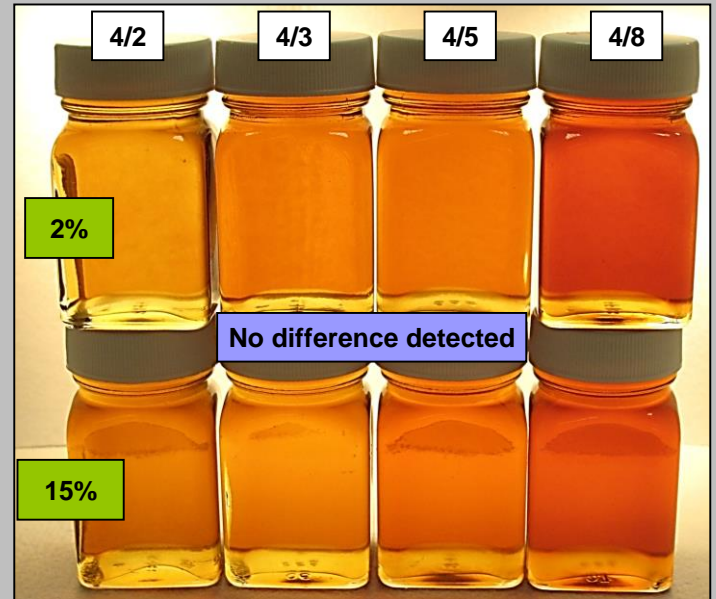
Results: Syrup composition and flavor

Composition/ Properties:

Very few (if any)
significant differences

Flavor:

No significant
differences found in
sensory evaluations



Conclusions

Effects of RO on syrup composition and flavor?

Slight to moderate effects on color

Minimal (if any) impacts on properties and chemical composition

No perceptible impacts on flavor in sensory evaluations



Photo: Gary Graham

Research: Reverse Osmosis

Effects of Sap Concentration with Reverse Osmosis on Syrup Composition and Flavor

A summary of experiments conducted at the University of Vermont Proctor Maple Research Center

*Abby van den Berg, Timothy Perkins, Mark Isselhardt
University of Vermont, Proctor Maple Research Center*

*Mary An Godshall
Sugar Processing Research Institute, Inc.*

*Steven Lloyd
United States Department of Agriculture Agricultural Research Service,
Southern Regional Research Center*

Concentrating maple sap with reverse osmosis (RO) significantly increases the efficiency and profitability of processing sap into syrup by reducing the amount of both fuel and time required to concentrate the material to syrup density in the evaporator. However, because this also reduces the amount of time sap is processed in the evaporator, and since most of the reactions from which the flavor and color properties of maple syrup are ultimately derived occur as sap is processed with heat in the evaporator, it is possible that this could result in impacts on the finished syrup, causing it to differ from syrup produced with raw sap.

with commercial maple equipment to investigate the potential effects of the use of RO on the composition, properties, and flavor of the maple syrup produced. The following is a brief, general summary of these experiments and the results observed. More comprehensive descriptions of each study can be found in the scientific journal articles published for each.

All experiments were conducted in the Maple Processing Research Facility at the University (MPRF) of Vermont Proctor Maple Research Center in Underhill Center, Vermont (UVM-PMRC) (Figure 1).

Results of all 3
experiments
outlined in
October 2015
Maple Digest
article

<http://www.uvm.edu/~pmrc>

“RO Effects on Syrup”

Higher concentration levels: >30%

Newest RO Technology:
Pre-concentrates sap to
30-40%



CDL 30+ RO

H₂O Innovation Super-
Concentrator™

Lapierre HYPERBRIX™

Memprotec



Study Objective

What are the impacts of ultra-high RO concentration on syrup **flavor**?



Sensory Evaluation Experiment:

Is the flavor of syrup produced with sap concentrated to 30-40 °Brix appealing and liked?

Is the flavor characteristic of pure maple syrup?

Syrup Samples

2016 Season

6 producers using
High-Brix

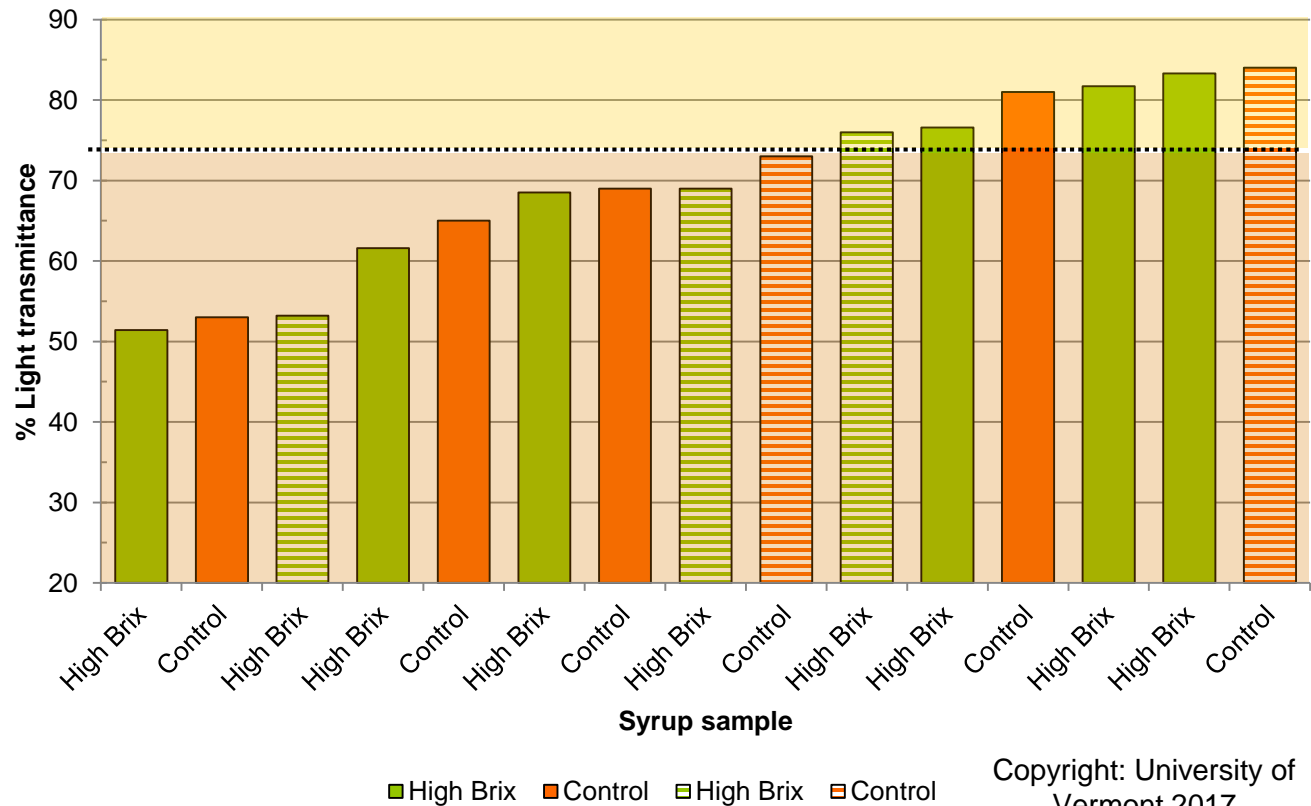
3 samples each:
Early, Middle, Late

%LT, °Brix, Organic
vs Conventional

**Matched Control
Samples**

Produced with
standard RO
(no steam, air injection, etc.)

Matched for
Color/Grade,
Organic/Conventional



Copyright: University of
Vermont 2017

Sensory Evaluation Experiment

46 panelists
recruited and
pre-screened:

Like maple syrup

Non-smokers

Familiar with current
grading system

4 Experiment
sessions



Sensory Evaluation Experiment

How much do you like or dislike the **overall flavor** of this syrup?

9-point hedonic scale

Dislike extremely → Like extremely

Sample ID# _____

1. Please indicate how much you like or dislike the **overall flavor** of this syrup:

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like or dislike	Like slightly	Like moderately	Like very much	Like extremely

(Is flavor of syrup made with High-Brix liked?)

Sensory Evaluation Experiment

How much do you agree or disagree with this statement:

“The flavor of this syrup is characteristic of pure maple syrup”

7-point Likert scale

Entirely disagree → Entirely agree

2. Please indicate how much you agree or disagree with this statement: “The flavor of this syrup is characteristic of pure maple syrup.”

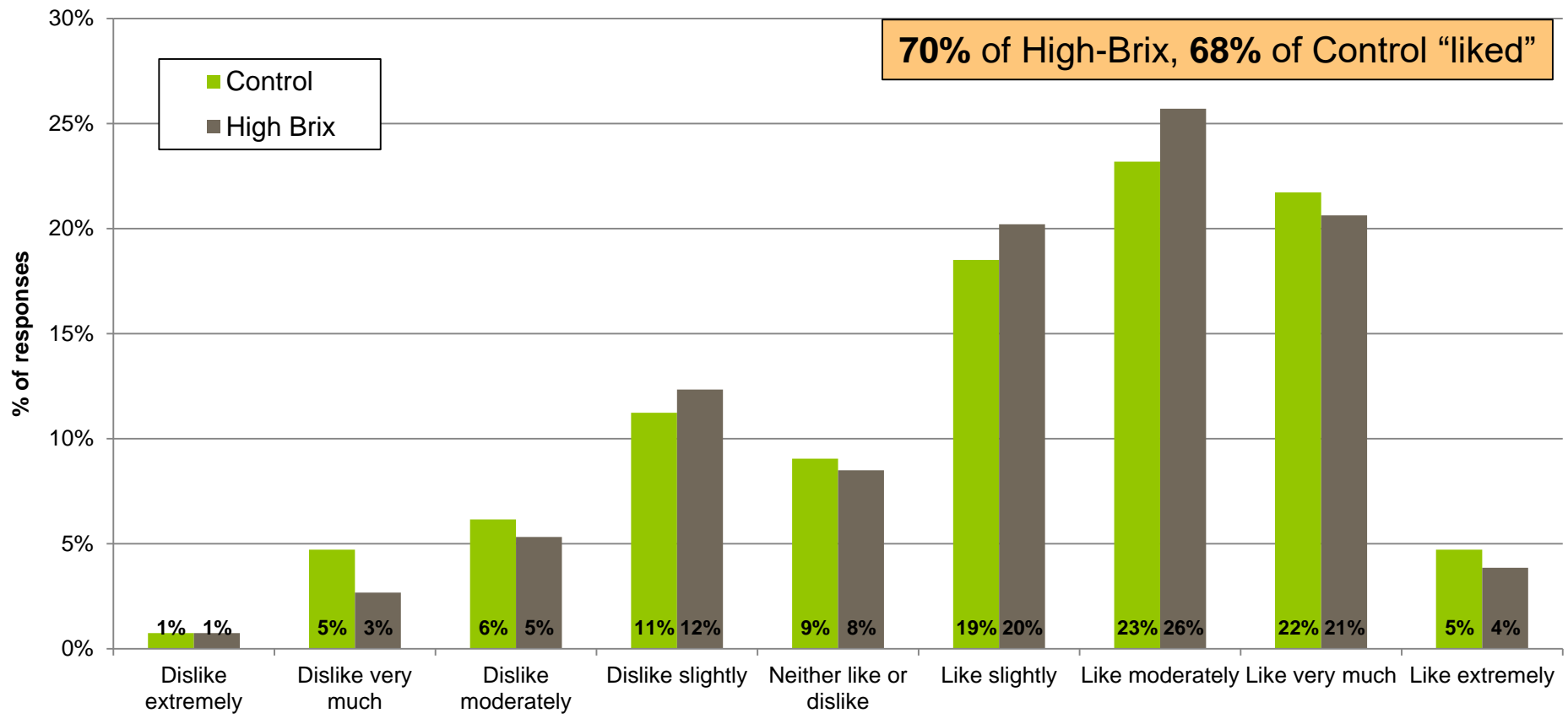
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Entirely disagree	Mostly disagree	Somewhat disagree	Neither agree or disagree	Somewhat agree	Mostly agree	Entirely agree

(Is flavor of syrup made with High-Brix characteristic of pure maple syrup?)

Results

Is the flavor of syrup produced with High-Brix processing liked?

Indicate how much you like or dislike the **overall flavor** of this syrup



70% of High-Brix, 68% of Control "liked"

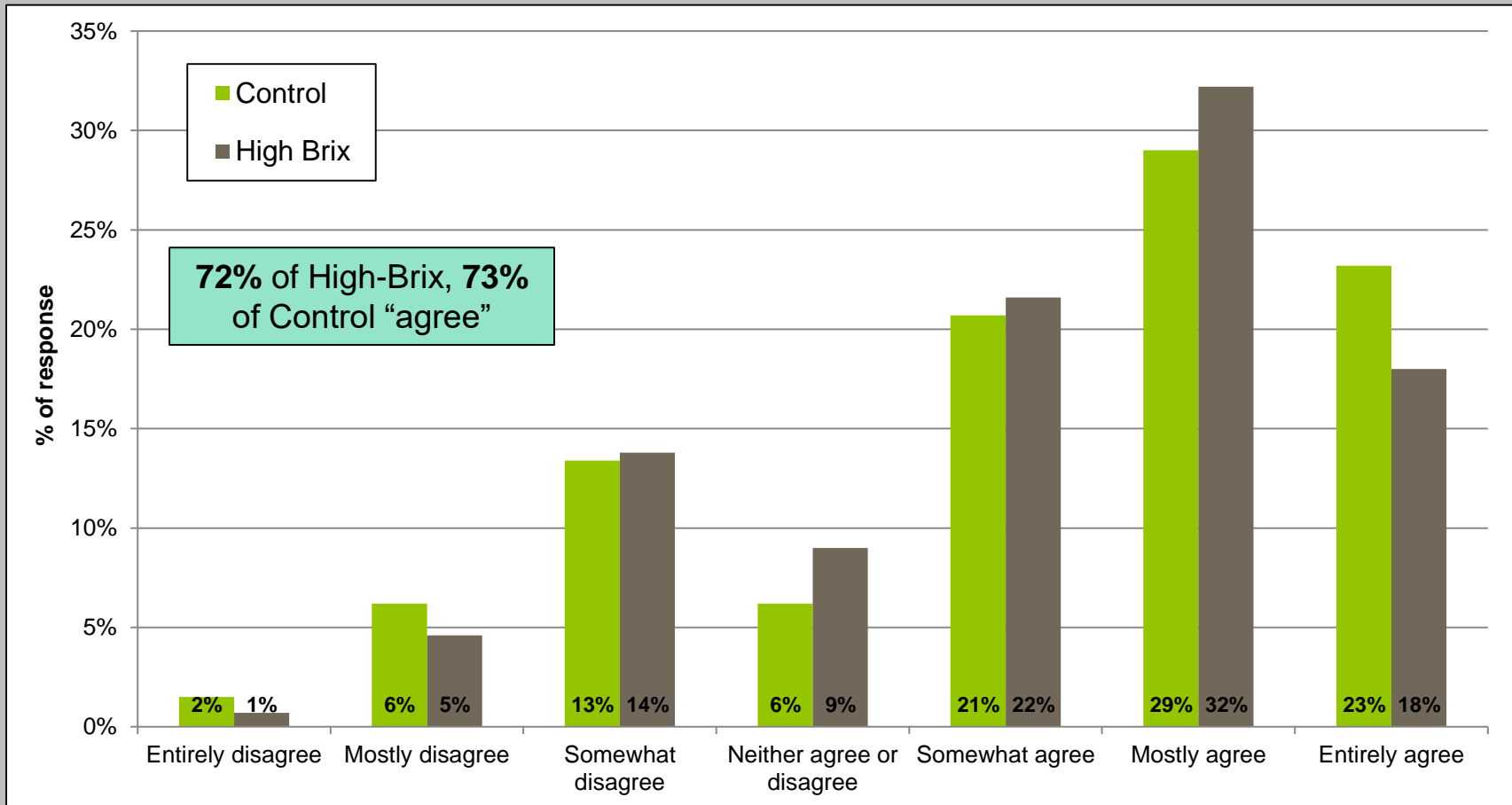
Overall average percentage of responses in each category across Control (n=6) and High Brix (n=9) samples.

$p < 0.9453$

Results

Is the flavor of syrup produced with High-Brix characteristic of pure maple syrup?

Indicate how much you agree or disagree with this statement:
“The flavor of this syrup is characteristic of pure maple syrup.”



Overall average percentage of responses in each category across Control (n=6) and High Brix (n=9) samples.

$p < 0.9375$

Preliminary Conclusions – High-Brix

Syrup made with High-Brix processing has flavor that is generally liked and characteristic of pure maple syrup



“Liking” and “characteristic of maple syrup” similar to syrup of the same color/grade made with standard RO processing

Flavor consistent with syrup of similar color grade



Thank you!

MPRF experiments supported by the UVM Agricultural Experiment Station, USDA CSREES grant #2008-34157-19186, and USDA NIFA grant #2010-34157-21008. High-Brix sensory experiment supported by the North American Maple Syrup Council Research Fund Chittenden County Maple Sugarmakers Association (MPRF evaporators)

Steve Bedard, Butternut Mountain Farm, Ben Dana, Douglas Edwards, Rock Gaulin, Jean-François Goulet, H₂O Innovation, Teague Henkle, Alan Howard, Jean Jones, Carl Lapierre, Lapierre Equipment, David Marvin, Marianne McKee, Miranda Moore, Joshua O'Neill, Ted Ortiz Y Pino, Jack O'Wrill, Brian Perkins, Eric Sorkin, Brian Stowe, and Joel Tilley

****Producers****

****Sensory panelists****

