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Chemical composition of five standard grades of pure maple syrup

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Maple syrup is a natural sugar product produced by evaporating the water from sap collected from sugar maple (Acer saccharum Marsh.) trees. It is categorized into four basic 'table' grades and one commercial grade (Marckres et al., 2006). The primary determinant of maple syrup grade is color, with lighter syrup generally demanding premium prices. All syrup must also meet standards of clarity, density and flavor.

Differences in color and flavor between individual grades are the result of differences in the chemistry of sap used to produce the syrup as well as chemical processes which occur during sap collection and processing, including microbial conversion of a portion of the sucrose in maple sap to invert sugars, as well as carmelization and Maillard reaction processes during evaporation (Perkins et al., 2006; Perkins and van den Berg 2009). These factors also yield differences in the general chemical composition of maple syrup and although syrup is generally composed primarily of sucrose, with small quantities of glucose, fructose, minerals, organic acids, phenolic compounds and amino acids (Potter and Fagerson, 1992; Perkins et al., 2006; Perkins and van den Berg 2009; Stuckel and Low, 1996), the relative quantities of each can vary widely between individual syrup samples (Stuckel and Low, 1996).

Due to the observed variation in the chemical composition between samples and the complexity of the mechanisms which result in the development of differential color and flavor, the chemical composition is expected to vary between the standard grades of maple syrup. To our knowledge, a published range of the chemical composition of the individual maple syrup grades is not currently available.

Thus, the objective of this study was to characterize the chemical composition of the five maple syrup grades, including their pH, conductivity, mineral and carbohydrate contents. In general, quantification of the range of chemical composition for each standard maple syrup grade will strengthen the existing knowledge of maple syrup chemistry. It may also identify characteristic chemical profiles of individual grades. Knowledge of the natural range in chemical composition, particularly for each grade, may also aid in the detection of adultered syrup by facilitating the detection of an unusual lack or abundance of a particular chemical constituent.

Materials and Methods

Ninety-nine pure, unblended maple syrup samples were collected in 2004 from individual producers across a wide geographic area. The percent light transmittance (%LT) at 560 nm was determined for each sample with a Hanna C219 maple syrup transmittance analyzer (Hanna Instruments, Woonsocket, RI, USA) using glycerol as

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a 100% transmittance standard. These values were used to categorize each syrup sample in one of the following five standard Vermont grades based on established values (Marckres et al., 2006): Fancy (%LT ≥ 75.0), Grade A Medium (60.5 ≥ %LT ≤ 74.9), Grade A Dark (44.0 ≥ %LT ≤ 60.4), Grade B (27.0 ≥ %LT ≤ 43.9) and Commercial (%LT < 27.0) (Table 1). The lower threshold for grade Fancy was expanded by 2% to compensate for the sensitivity and accuracy of the grading instrument.

Table 1. Light transmittance values used to determine the grade of maple syrup samples

		Light transmitance (%)		
Grade	*n*	Min	Max	Mean
Fancy	10	73.0	77.7	75.2 ± 0.6
A Medium	20	60.6	72.9	67.5 ± 0.7
A Dark	16	44.5	60.1	52.5 ± 1.2
B	25	27.0	43.5	32.5 ± 0.8
Commercial	28	3.3	25.8	18.3 ± 1.2

Conductivity (µS/cm2) and pH of each sample were measured with an Oakton pH/CON 10 dual probe meter (Oakton Instruments, Vernon Hills, IL). Nitrogen (N) content (%) of each syrup sample was determined with a Thermo Electron Corp Flash EA 1112 Series NC Elemental Analyzer (Thermo Finnigan Italia S.p.A. Rodana, Milan, Italy). For mineral analysis, 0.5 g of each syrup sample was digested with 10mL concentrated nitric acid for 15 min at 190 °C and 2.1 MPa pressure. Digested samples were then analyzed for calcium, iron, magnesium, manganese, phosphorous, potassium, sodium, sulfur and zinc content (mg/kg) by inductively coupled plasma atomic emission spectroscopy (IC-PAES, PlasmaSpec 2.5, Leeman Labs, Hudson, NH, USA). Total percentages of glucose, fructose and sucrose in each sample were determined by a commercial food analysis laboratory using high-performance liquid chromatography (HPLC). Sample sizes for carbohydrate analysis differed from the other analyses due to sample loss from spoilage during transport.

Minimum and maximum values, means, and standard errors were calculated for each parameter for each syrup grade. One-way analysis of variance was used to test the hypothesis that means of each parameter were equal between syrup grades. The nonparametric Wilcoxon Rank Sums procedure and Kruskal-Wallace tests were used to test this hypothesis for parameters which were not normally distributed. (Statistical assumptions of normality were verified by examining normal probability plots, and homogeneity of variance assumptions were verified

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Table 2. Conductivity and pH of samples representing five maple syrup grades

		Conductivity (µS/cm^2)			pH		
Grade	*n*	Min	Max	Mean	Min	Max	Mean
Fancy	10	96	241	167.7 ± 15.3	5.8	6.7	6.2 ± 0.6
A Medium	20	132	259	183.2 ± 7.2	5.6	7.3	6.3 ± 0.6
A Dark	16	114	238	174.8 ± 8.1	5.8	7.2	6.2 ± 0.6
B	25	104	303	202.8 ± 10.0	5.5	7.1	6.2 ± 0.6
Commercial	28	113	318	195.4 ± 8.7	5.5	7.1	6.1 ± 0.8
P				0.1088[a]			0.4342

P-values are for tests of hypotheses that parameters were equal between syrup grades. [a] indicates standard F-test used; all other comparisons used nonparametric Kruskal-Wallace tests.

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with Levene's and Brown-Forsythe's tests for normally and non-normally distributed populations, respectively.)

Results and Discussion

Conductivity and pH values (Table 2) were within the general range published for maple syrup (Perkins et al., 2006; Perkins and van den Berg 2009). Values varied within samples of each syrup grade, however neither pH nor conductivity varied significantly between grades. In addition, mean pH and conductivity did not exhibit consistent patterns of increasing or decreasing values from lighter to darker syrup grades. The results indicate individual syrup grades do not have characteristic values for pH or conductivity.

Carbohydrate compositions of the different grades of syrup (Table 3) were within the general range published for maple syrup (Perkins et al., 2006; Perkins and van den Berg 2009). Glucose and fructose contents have been anecdotally reported to increase, and sucrose content to decrease, from lighter to darker grades of maple syrup. However, the samples analyzed in this study did not follow this pattern. Although mean values of glucose and fructose varied significantly between the different grades of syrup, values were not consistently greater in darker than in lighter grades. Sucrose content was also not consistently lower in darker than in lighter syrup grades. These results indicate that individual syrup grades do not have characteristic carbohydrate compositions.

Table 3. Carbohydrate composition of samples representing five maple syrup grades

		Fructose (%)			Glucose (%)			Sucrose (%)		
Grade	*n*	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Fancy	9	0.0	0.4	0.1 ± 0.0	0.4	1.6	0.7 ± 0.1	63.1	69.3	65.9 ± 0.6
A Medium	12	0.0	1.0	0.7 ± 0.1	0.2	1.1	0.6 ± 0.1	62.4	67.8	65.1 ± 0.5
A Dark	11	0.0	0.9	0.3 ± 0.1	0.2	1.4	0.7 ± 0.1	60.5	73.8	66.2 ± 1.1
B	15	0.0	0.9	0.5 ± 0.1	0.0	1.1	0.4 ± 0.1	63.0	70.1	67.1 ± 0.5
Commercial	8	0.1	1.1	0.6 ± 0.1	0.1	1.2	0.6 ± 0.1	59.4	70.0	65.4 ± 1.3
P				0.0210			0.0375			0.3653[a]

P-values are for tests of hypotheses that parameters were equal between syrup grades.
[a] indicates standard F-test used; all other comparisons used nonparametric Kruskal-Wallace tests.

Mineral composition values (Table 4) were within the general range published for maple syrup (Perkins et al., 2006). For most of the minerals analyzed, content ranged widely within samples of each syrup grade. In addition, the ranges of composition for each grade often overlapped those of other grades and very few mineral constituents varied significantly between syrup grades. With the exception of calcium, mean mineral composition of each grade did not exhibit consistent patterns of increase or decrease from lighter to darker syrup grades. These results indicate mineral content can vary markedly between individual syrup samples and that syrup grades do not exhibit unique, characteristic mineral compositions related to light transmittance.

Conclusions

The results of this study confirm previous findings that chemical composition varies substantially between individual samples of maple syrup (Stuckel and Low, 1996; Perkins et al., 2006; Perkins and van den Berg 2009). In addition, these results indicate that individual grades of maple syrup do not have unique, characteristic chemical compositions. Although this study did not identify consistent chemical profiles for each syrup grade, the established ranges expand the existing knowledge of maple syrup chemistry and may facilitate the detection of economically adultered syrup.

Acknowledgements

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Table 4. Mineral composition of samples representing five maple syrup grades

		N (%)			Ca (mg/kg)			Fe (mg/kg)			K (mg/kg)			Mg (mg/kg)		
Grade	*n*	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Fancy	10	0.00	0.06	0.03 ± 0.01	381	602	479 ± 27	0.01	13.90	3.42 ± 2.23	1492	2575	1864 ± 136	96	264	172 ± 19
A Medium	20	0.01	0.06	0.03 ± 0.00	361	984	617 ± 38	0.01	60.99	5.02 ± 3.17	1424	2865	1983 ± 93	73	323	196 ± 15
A Dark	16	0.00	0.07	0.03 ± 0.00	278	1466	691 ± 69	0.01	13.04	2.13 ± 0.86	1415	2509	1951 ± 88	25	543	171 ± 32
B	25	0.00	0.08	0.03 ± 0.00	446	1492	900 ± 65	0.01	6.17	2.25 ± 0.42	963	2795	1888 ± 96	29	500	156 ± 19
Commercial	28	0.00	0.07	0.03 ± 0.00	501	2494	1195 ± 88	0.01	48.68	6.63 ± 1.94	1281	3319	2132 ± 115	43	284	174 ± 12
P				0.8179[a]			0.0001			0.0601			0.7233			0.1677

		Mn (mg/kg)			Na (mg/kg)			P (mg/kg)			S (mg/kg)			Zn (mg/kg)		
Grade	*n*	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Fancy	10	8.95	80.14	33.89 ± 9.14	0.01	4.17	1.41 ± 0.59	0.01	9.79	2.93 ± 1.50	0.01	0.01	0.01 ± 0.00	0.7	19.8	6.6 ± 2.7
A Medium	20	1.41	72.54	22.31 ± 4.45	0.01	218.43	20.05 ± 11.83	0.01	29.14	7.47 ± 2.32	0.01	84.00	24.32 ± 5.55	1.3	63.8	15.6 ± 4.4
A Dark	16	1.72	164.43	29.64 ± 11.78	0.01	492.13	48.28 ± 33.58	0.01	62.56	10.62 ± 4.37	0.01	69.44	15.68 ± 6.13	0.01	35.7	6.1 ± 2.4
B	25	1.26	99.38	31.08 ± 6.25	0.01	261.43	66.71 ± 18.18	0.01	58.87	19.26 ± 3.50	0.01	100.00	19.60 ± 5.51	0.3	361.4	47.9 ± 15.8
Commercial	28	0.01	223.24	37.04 ± 10.06	1.66	193.18	17.64 ± 6.63	0.01	90.70	17.92 ± 4.63	0.01	82.05	20.05 ± 4.56	1.6	527.2	39.1 ± 18.7
P				0.6003			0.0004			0.0615			0.0286			0.0121

P-values are for tests of hypotheses that parameters were equal between syrup grades. [a] indicates standard F-test used; all other comparisons used nonparametric Kruskal-Wallace tests.

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