Variation in Sap Sugar Content Across States

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Sap sugar concentration varies from tree-to-tree, from one location to another, within a season, from one season to the next, and even within individual sap runs. These changes arise from several factors, primarily due to genetic and environmental factors including soil nutrition, weather, and tree size/stature and health. Typically, the level of sucrose in sap averages around 2.0°Brix over a season, but can range much lower and higher (Perkins et al. 2022). Sugar maple trees generally produce slightly sweeter sap than red maple (van den Berg 2022, Perkins et al. 2024).

Within any individual season, sap sugar levels tends to peak early then trend downward as the season progresses, with slight upward excursions sometimes occurring after freeze periods (Perkins 2022). It should be noted that the sugar that is transformed into syrup was once produced during the process of photosynthesis over previous growing seasons. Once produced, and if not used immediately by the tree to support its normal function, the sugar is converted to starch (a more suitable material for long-term storage through enzymatic activity. The timing and rate of conversion of starch back to sugar is limited to some degree by temperature which could also impact the SSC in maple sap (Sauter 1973). In general, there are no significant differences in sap sugar concentrations between gravity or vacuum collection (Wilmot et al. 2007), but producers using vacuum will see lower values after several days of prolonged thaws (Perkins 2022).

Some seasons tend to have somewhat higher or slightly lower sugar in sap than average. The exact causes for this are unknown, however regional influences such as conditions during the growing season, drought, seed production, tree nutrition, and other factors are all likely to be involved (Rademacher et al. 2023), although the strength of these relationships have not been well determined.

Similarly, there is little information about how sap sugar varies across the maple producing region. Raap et al. (2019) in a study of a limited number of sites found that sap levels were negatively related to previous growing season temperature, meaning that higher temperatures from May to October preceding the sap flow season was associated with reduced sap sugar. These results were contrasted by another study (Duchense et al. 2014) that found that sap sugar concentration appeared to increase following higher temperatures in the previous growing season.

The U.S.D.A. National Agricultural Statistics Service (NASS) conducts an annual survey of maple producers in several states. From 2013-2015, the survey asked about the ratio of sap to syrup (SSR or the number of gallons of sap required to make a gallon of syrup). A low SSR means more sugar in the sap (a higher sap sugar concentration), thus requiring fewer gallons of sap to make a gallon of syrup, whereas a high SSR means a lower sap sugar concentration.

NASS published SSR values) for ten of the higher syrup producing states. There is no information available for how many producer responses were used to generate the reported values. Likewise, no information is available to understand the methods producers that used to determine their SSR to respond to NASS's request. In addition, finished syrup can have slightly different density requirements in different states, which would somewhat affect the reported SSR values. Given the lack of consistency in sampling methods (precision/accuracy of instrument, number and timing of samples taken to generate the estimate and to what degree the producer calibrated and properly used their instruments, we can only take the results at face value in the subsequent analysis.

Figure 1 shows the SSR for each state for 2013, 2014, and 2015. Across all states and all three years, SSR ranged from a low of 34 gal/gal to a high of 52 gal/gal, with an average of 44.6 gal/gal across all years and states. Interestingly, 6 of 10 states in 2013 had exactly the same SSR value of 46 gal/gal. NASS verified those values in their database, but provided no further clarification.

It may simply reflect the fact that SSR was in fact similar across a wide geographic range, or that as a new survey question respondents picked a general round number. Despite this, we see similar trends and relationships in the subsequent two years. Therefore, the data from 2013, although unusual, was retained in this analysis. In 2013, ME and WI clearly had lower SSC than all the other states assessed. These two states remained at the lower end of the SSR spectrum for the next two years, but the margin was far less pronounced. OH and PA tended to have slightly higher values than other states. Most of the other states grouped at similar SSR levels each year, with just slight variations.

In most cases, absolute changes in SSR from one year to the next averaged 6.3%, but occasionally changes in SSR of up +20% (ME from 2013 to 2014) and -13% (NH from 2014 to 2015) were found. Some states (MA, NY, MI) exhibited relatively stable or minor changes in SSR across the three years.

The year 2013 had an average SSR of 43.8, with 2014 and 2015 coming in a 45.7 and 44.4. Averages mask the fact that two states (ME and WI) had considerably lower SSR (sweeter sap) than the other states that year. Similarly, CT and PA had relatively high SSR (less sweet sap) values in 2015 compared to the other states. In 2013 and 2014, 8 of 10 states had SSR levels higher than 43 gal/gal. In 2015, 7 of 10 states had

SSR at approaching or below 43 gal/gal, suggesting a "sweeter" sap year across a broad area of the maple producing belt.

Of some note, there was only a low relationship ($r^2 < 0.20$) between SSR and syrup yield, suggesting that, in general, sap volume over a season has a much stronger impact on syrup yield. Therefore, high SSR is probably less important to syrup production than is commonly thought, except in extremely low sap sugar content seasons in some areas.

In examining these results, northern states appeared to have slightly lower SSR (sweeter sap), while more southern states tended to have lighter SSC (less sweet sap). When we examined the relationship between latitude (using the geographic center of each state) and SSR, we found there was a reasonably robust relationship (r2 = 0.78, Figure 2). This suggests that latitude (how far north a state is from the equator) is strongly related to SSR, with a reduction of about 0.1° Brix per degree of latitude southward. Admittedly, state geographic center doesn't necessarily represent the climatic center or the center of distribution of maple production in these states. Further examination would be necessary to explore this relationship better. Whether this is just a spurious correlation or there is some physiological relationship between SSR and climate is unknown, but the question has relevance to climate change and requires further study.

Literature Cited

Duchesne, L., Houle, D., Côté, M.-A., Logan, T., 2009. Modelling the effect of climate on maple syrup production in Québec, Canada. For. Ecol. Manage. 258, 2683–2689.

Perkins, T.D. and M.L. Isselhardt. 2013. The Jones Rule of 86 Revisited. Maple Syrup Digest 25A:26-28.

Perkins, T.D. R.B. Heiligmann, M.R. Koelling and A.K. van den Berg. (Editors). 2022. North American Maple Syrup Producers Manual. Third Edition. University of Vermont and the North American Maple Syrup Council, Burlington, VT. 434 p. https://mapleresearch.org/pub/manual/

Perkins, T.D., A.K. van den Berg, M.L. Isselhardt, W.T. Bosley, S.J. Abair, and B.M. Haynes. 2024. Red Maple – Tap 'Em If You Got 'Em. The Maple News (in press).

Raap, J.M., D.A. Lutz, R.D. Huish, B. Dufour, S. Ahmed, TL. Morelli, and K.A. Stinson. 2019. Finding the Sweet Spot: Shifting Optimal Climate for Maple Syrup Production in North America. For. Ecol. Mgmt. 448: 187-197.

Rademacher, T., M. Cliche, ´E. Bouchard, S.Y.S. Kurokawa, J. Rapp, J., A. Deslauriers, C. Messier, S. Rossi, J. Dupras, ´E. Filotas, and S. Delagrange. 2023. TAMM review: on the importance of tap and tree characteristics in maple sugaring. For. Ecol. Mgmt. 535: 120896.

Sauter, J.J., Iten, W., and Zimmermann, M.H. 1973. Studies on the release of sugar into the vessels of sugar maple (Acer saccharum). Canadian Journal of Botany. 51: 1-8.

van den Berg, A.K., T.D. Perkins, M.L. Isselhardt, B.M. Haynes, and W.T. Bos ley. 2022. Total Yields from Red Maples. CDL's Way 2: 22-23.

Wilmot, T.R., T.D. Perkins, and A.K. van den Berg. 2007. Vacuum Sap Collection: How High or Low Should You Go? Maple Syrup Digest 19A(3): 27-32.

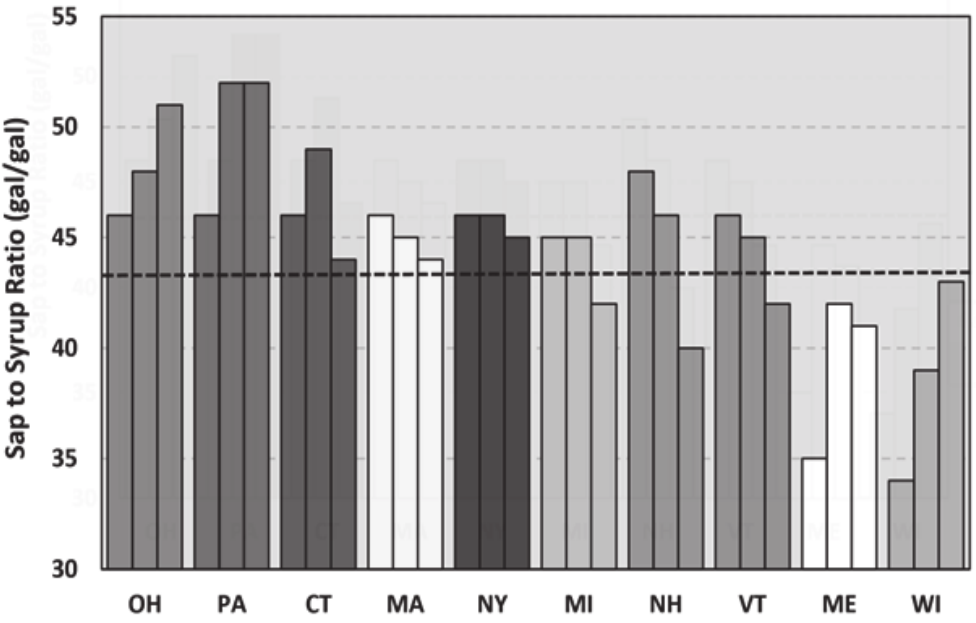


Figure 1. Average annual sap-to-syrup ratio (SSR) for ten states from 2013-2015. The bars for each state group represent 2013, 2014, and 2015, respectively, from left to right. The dashed line represents 2° Brix point level at which 43 gal of sap are required to make 1 gal of syrup at 65.5° Brix according to the Jones Rule of 86. Minimum maple syrup density in the U.S. is currently 66.0° Brix, but is higher in some states.

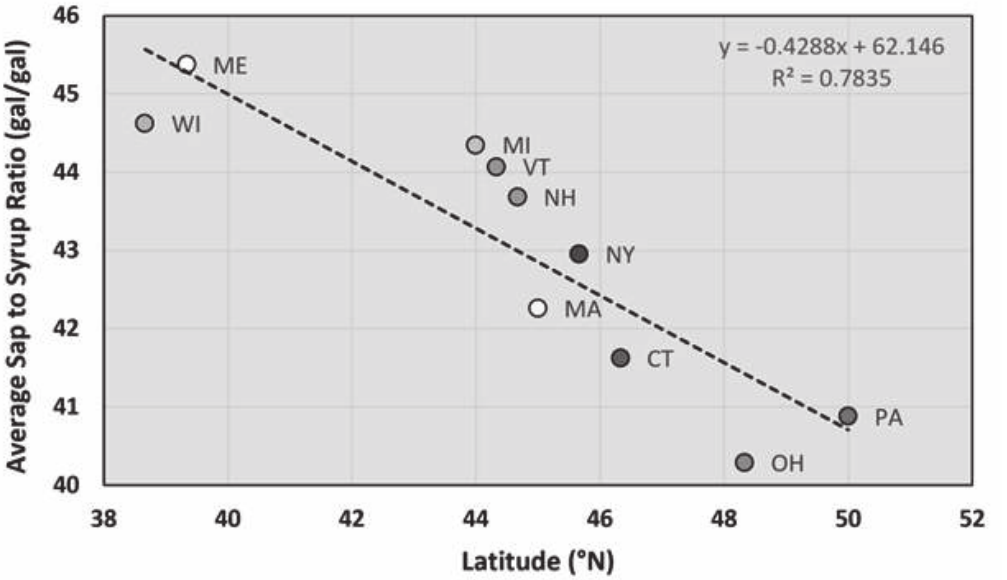
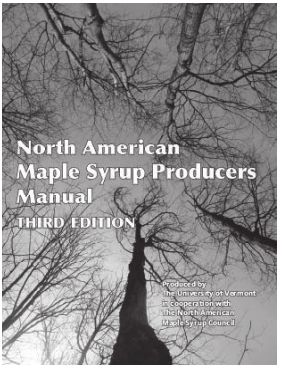


Figure 2. Average sap to syrup ratio for each state from 2013-2015 by geographic center (latitude) of each state. The dashed line represents the linear regression.



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