Reducing Maple Sap Spoilage

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Overview '

Maple sap is a perishable product that will spoil when stored improperly or for extended periods of time. As it exits the tree, it is contaminated with bacteria, yeast, and molds, which can spoil the sap by consuming its resources (e.g. sugars) or by releasing byproducts (e.g. enzymes, acids, aromas) resulting in color, texture, flavor and odor changes in the sap. Flavors and textures developed in spoiled sap can persist in maple syrup and other value-added products; therefore, proper care of maple sap is essential to produce quality products.

Composition of Maple Sap

Maple sap contains water, sucrose, organic acids (malic, succinic, and oxalic), minerals, phenolics, and flavonoids (Yuan et al. 2013). Its composition can differ throughout the season and in different locations. Throughout a season, total phenolics and mineral concentrations increase in maple syrup. While across locations, the pH, syrup color, and mineral content can differ (Nimalaratne et al. 2020). A variation in sap composition particularly pH, sugars, and minerals impact microbial activity and subsequently shelf-life
(Jay et al. 2005).

Spoilage and Quality Decline

What is sap spoilage?

Maple sap spoilage can appear as sour, fermented, or musty flavors and odors, cloudy appearance, or formation of a clear to opaque, viscous, string-like texture known as “ropy” sap. The type of spoilage that occurs depends on the microorganisms present. Sour off flavors are associated with bacteria (Lagacé et al. 2015), fermentation is associated with yeast (Whitfield, 1998), musty flavors are associated with bacteria and fungi (Whitfield, 1998), and ropy sap is associated with bacteria (Lagacé et al. 2018). Due to the variety and complexity of spoilage, broad-spectrum approaches are used to reduce microbial contamination and growth.

How can spoilage be reduced?

Sap spoilage can be minimized by both maintaining optimal storage conditions, particularly at low temperatures and proper sanitation of collection and storage materials. Temperature control is essential in reducing spoilage. In maple sap and many other food products, two types of bacteria are prominent - cold-loving, psychrophilic bacteria and moderate-temperature loving, mesophilic bacteria. Cold-loving bacteria grow between 32 to 68 °F, while moderate-temperature loving bacteria grow best between 77 to 104 °F. (van Lier et al. 1997). Both types are known to grow in maple sap (Lagacé et al. 2006a;
Lagacé et al. 2018) and both have

significantly lower growth rates below 40 °F (van Lier et al. 1997). It is recommended to store sap below 40 °F to maintain quality.

Another key component of temperature storage is consistency. Temperature fluctuations will increase the rate of sap spoilage. For instance, sap stored at 73 °F for eight hours followed by 39 °F for 16 hours spoiled at the same rate as sap stored consistently at 59 °F (Lagacé et al. 2018).

In addition to temperature management, cleaners and sanitizers can be used to remove and inactivate microorganisms growing on surfaces (McDonnell and Russell, 1999). Cleaning refers to the physical removal of material from a surface while sanitizing is an inactivation of the microorganisms on a surface. Sodium hypochlorite and peracetic acid are effective sanitizers for sap collection and storage materials, including the removal of biofilms (Lagacé et al. 2006b). To avoid off-flavors in sap and syrup, sanitizers can be removed by rinsing prior to sap collection. All sanitizers used in sugarbushes must be approved for use on food contact surfaces by the Environmental Protection Agency (EPA) and have an EPA registration number.

How to determine if sap is spoiled?

Sap spoilage can appear in numerous forms. The key indicators that can be used to detect sap spoilage are off-appearance, off-odors, and/or a decline in pH.

To illustrate the quality decline and off-odor development that can occur, sap (2.1 °Brix) was harvested in cleaned and sanitized food grade buckets from sugar maples (Acer saccharum) in the Arnot Forest Sugarbush. Sap was evaluated for quality decline (off- appearance and off-odors, °Brix, and pH) and microbial contamination during storage at 41 °F (5 °C) and 50 °F (10 °C) for up to 12 days. The data presented shows trends that occur when sap is stored at warmer temperatures and the difference in spoilage rate between storage temperatures.

The sap was clear and free of debris at collection. and appearance was consistent throughout storage, even as sap spoiled (Figure 1). By 6 days, sap stored at 50 °F developed a slightly sour aroma.

Similarly, sap stored at 41 °F developed a sour aroma by 12 days of storage. In both storage conditions, no other aromas, textures, or cloudiness were perceived.

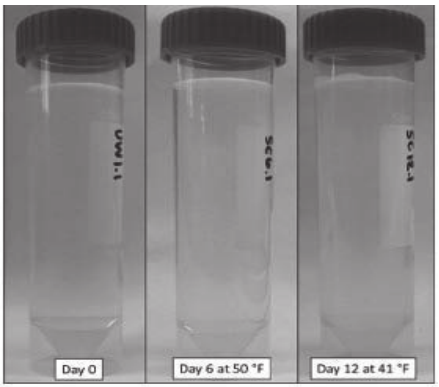

Figure 1. Visual appearance of maple sap stored immediate after harvest (left) and following development of off-odors at 50 °F (6 days; middle) or at 41 °F (12 days; right).

While sourness is a common indicator of spoilage, spoilage can appear in any of the forms previously mentioned.

To evaluate the **quality** of maple sap, take note of the initial appearance and aroma of the sap. Continue to monitor the sap each day and record any changes. Dispose of sap if any of the following appear: a sour, fermented, or musty flavor or odor, a cloudy appearance, or a ropy texture.

The **°Brix** will decline over time as bacteria use sugars, a carbohydrate, as a resource (Sperber and Doyle, 2009). However, measuring changes in °Brix is not a reliable indicator of spoilage in raw sap. In this study, the °Brix was unchanged throughout 6 days at 50 °F and 12 days at 41 °F (data not shown). In a study by Lagacé et al. (2018), °Brix declined within three days of storage in concentrated maple sap (8 °Brix) stored at warmer temperatures (59 °F and 73 °F). In saps with lower sugar concentrations or those stored at a lower temperature, the sugar consumption by bacteria may not be detectable with a refractometer until later stages of spoilage.

A decline in **pH** can be used to indicate sap spoilage. This is because some bacteria consume resources in sap and leave acids as a byproduct (Whitfield, 1998). However, the pH in fresh sap can range from 6 to 7.4 and it differs across seasons and locations (Nimalaratne et al. 2020). To use pH as a quality indicator, measure and record the initial pH of the sap with a pH meter or pH test strips. Continue to monitor the pH throughout sap storage. Raw or unconcentrated sap stored at or below 50 °F can be evaluated daily, while sap stored above 50 °F should be monitored more frequently. Concentrated sap (8 °Brix) stored at or below 40 °F can be evaluated daily, while this sap stored above 40 °F should be monitored more frequently, based on findings from Lagacé et al. (2018). If a decline greater than 0.5 units in pH occurs, as shown in Figure 2, that is an indication that the sap may be spoiled. In the example presented in Figure 2, a significant decline in pH was observed the same day in which a sour aroma developed in sap.

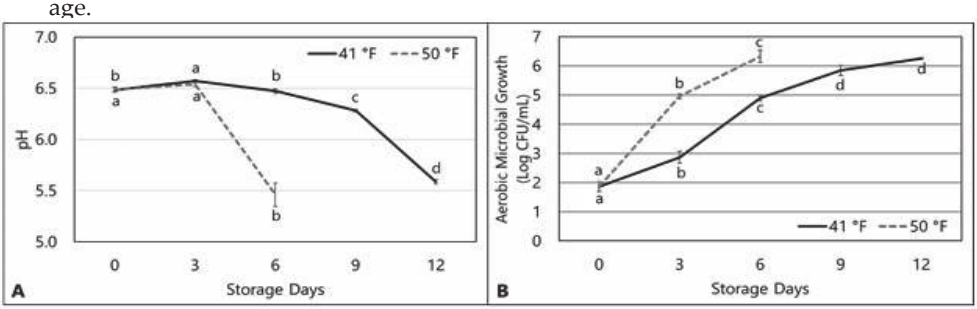

Figure 2. pH (A) and aerobic microbial growth (B), measured through a total aerobic plate count, of maple sap during storage at 41 °F and 50 °F. Vertical bars represent the standard error (n=6). Different letters indicate significant differences at $P < 0.0001$ level of probability. Sap was collected from the Arnot Forest Sugarbush in Van Etten, NY during the 2024 maple season.

Microbial growth is assessed by counting the number or microorganisms present in a defined area at a known concentration. This concentration, commonly referred to as the microbial load, serves as a valuable indicator of spoilage or as an indication of a properly sanitized surface. The microbial load can be measured using an aerobic plate count method, with results expressed as the number of colony forming units (CFU) or viable microbial cells (Maturin and Peeler, 2001). In microbiology, a food product is generally considered spoiled the microbial load reaches 6 log CFU/mL, which is equivalent to 1 million colonies. However, obtaining an aerobic plate count requires time, often taking several days to weeks, as bacteria, yeast, and molds must grow on nutrient media before colonies can be counted.

In this study, the microbial load of sap increased from 1.9 log CFU/mL on Day 0 to 6.3 log CFU/mL by Day 6 at 50 °F and Day 12 at 41 °F (Figure 2b). To an extent, the rate of spoilage will accelerate as temperature increases, particularly within the "Danger Zone" – the temperature range between 40 °F and 140 °F where bacterial growth is more rapid (USDAFSIS, 2020). Initial microbial load also influences sap shelf-life, with higher initial microbial loads leading to faster spoilage. Sap collected in clean, sanitized buckets or tubing will have a lower microbial load, resulting in a longer shelf-life compared to sap collected from unclean equipment.

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