Melting Temperature of Alternative Sugars and Sweeteners

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Abstract

In cooking, sugar is used to provide a sweet flavour for many dishes. Sugar melts during the cooking process and many alternative sugars and sweeteners are now of public interest. An investigation on the melting temperatures of coconut sugar, erythritol sweetener and xylitol sweetener was conducted. The study objective was to discover the melting points of these alternative sugars and sweeteners by using sugar calibration data as a standard. This data provided insight on the melting temperature, a physical property, of the alternative sugars and sweeteners. Oven calibration of sugar resulted in a calculated temperature difference, which allowed melting temperatures of the other sugars to be found. Data was compiled and assessed with statistical analysis, and there was no variance within each treatment group. Overall, using sugar to calibrate the temperature of the oven permitted average melting temperature determination of the three treatments. Further directions for this study would involve temperature accuracy and verification.

Introduction

Alternative sugars and sweeteners have become increasingly common in the marketplace. They have recently generated public interest as people are becoming more willing to try alternative sugars and sweeteners in attempt for a heathier diet and lifestyle. Knowing the melting temperature of alternative sugars and sweeteners allows proper cooking and prevent burning or overheating. The person cooking will know how to handle these alternative sugars and sweeteners effectively, while utilizing the properties of the substances to the dish's benefit.

Melting is the phase transition from a solid, crystalline state to a liquid state (Roos et al. 2013). For sugar, it would be changing from a crystalline, lattice structure into a liquid, melted form. The temperature at which a substance melts is the melting point, which is a unique characteristic for each substance. Sugar crystals melt in a time and temperature dependent manner (Roos et al. 2013). Alternative sugars and sweeteners that were investigated in this study were coconut sugar, erythritol sweetener and xylitol sweetener. Coconut sugar is produced from coconut palm tree sap, which gets heated until it crystalizes (Wrage et al. 2019). Erythritol is produced by microbes, such as yeasts, has food and pharmaceutical applications and reduces dental caries (Moon et al. 2010). Xylitol is a naturally occurring sugar alcohol that comes from xylan in birch trees, and it also reduces dental caries (Ly et al. 2006). Since erythritol and xylitol both have the ability to reduce dental caries, they are more attractive than sugar in terms of oral health maintenance.

This project used sugar and its known melting temperature of 367F to calibrate the oven temperature. Subsequently, this information was used with the oven dial temperature at which various alternative sugars and sweeteners melt in order to determine the actual melting point temperature of these substances. The objective of the study was to use the oven calibration data as a baseline for determining melting points of other sugars. This investigation was important in learning specifically about each alternative sugar or sweetener's melting temperature, which would then allow consumers and chefs to learn to fully optimize the melting property of various sugars in cooking.

If my oven temperature can be calibrated with a sugar of known melting point, then the melting point temperature in Fahrenheit of various alternative sugars and sweeteners can be accurately determined. This because collected temperatures are based on the oven dial, then calculating the actual oven temperature based on oven calibration results. Determination of the melting temperatures of alternative sugars and sweeteners were predicted to be possible from the initial oven calibration with sugar.

Methods

The experiment was done in a toaster oven and the sugar used for calibrating the oven temperature was Roger's natural granulated sugar. For the alternative sugars and sweeteners tested, Everland organic coconut sugar, Krisda organic erythritol sweetener and Krisda xylitol sweetener were used. The three alternative sugars and sweeteners were pure (100%) and did not contain any other sugars mixed together by the manufacturers, as noted in the ingredients list of each. Sugar, erythritol and xylitol sweeteners had white, crystalline appearances, while coconut sugar consisted of brown, sand-like particles.

From a previous oven calibration exercise, it was determined that my oven was running 72F hot; In other words, 295F on the oven dial reflected 367F as the actual temperature. Using this information, the project used this temperature as starting point. The difference between the oven dial reading and the actual temperature of the oven was re-determined with sugar as a control. By using the melting temperature of sugar (367F) relative to the reading on the oven dial, the calibration temperature difference was determined. The melting temperature of the control sugar served as the baseline as to what adjustment on the dial was actually 367F. Taking that into account, this project was able to determine melting points of the other sugars and sweeteners by adjusting with the calibration temperature difference of the oven.

First, the oven was preheated to 295F (dial temperature). Three aluminum foil boats were created, and 1 teaspoon of sugar (control) was placed inside each. Once the oven reached the set temperature, the sugar boats were placed in the oven for fifteen minutes. Whatever happened to the sugar in each sugar boat was deemed independent from the other two sugar boats as these served as three replicates. Afterwards, there were either of the two scenarios: A) If the sugar did not melt, the sugar was removed from oven, the oven temperature was increased by 5F, and after waiting until the set temperature had been reached, the sugar boat was replaced in the oven for fifteen minutes – this was repeated until the sugar melted. B) If the sugar melted, the sugar was removed from oven, the oven temperature was decreased by 5F upon cooling of the oven, an aluminum foil boat with new sugar was made, and the sugar boat was placed in the oven for fifteen minutes after the set temperature had been reached – this was repeated until sugar does not melt. Regardless of the scenario obtained, the process was repeated in 5F increments until the lowest temperature at which sugar melts was found for the three replicates. An example of melted and unmelted sugar is shown in Figure 1. This dial temperature value was used to calculate the calibration temperature difference from the melting point of sugar (367F) for each of the three replicates.

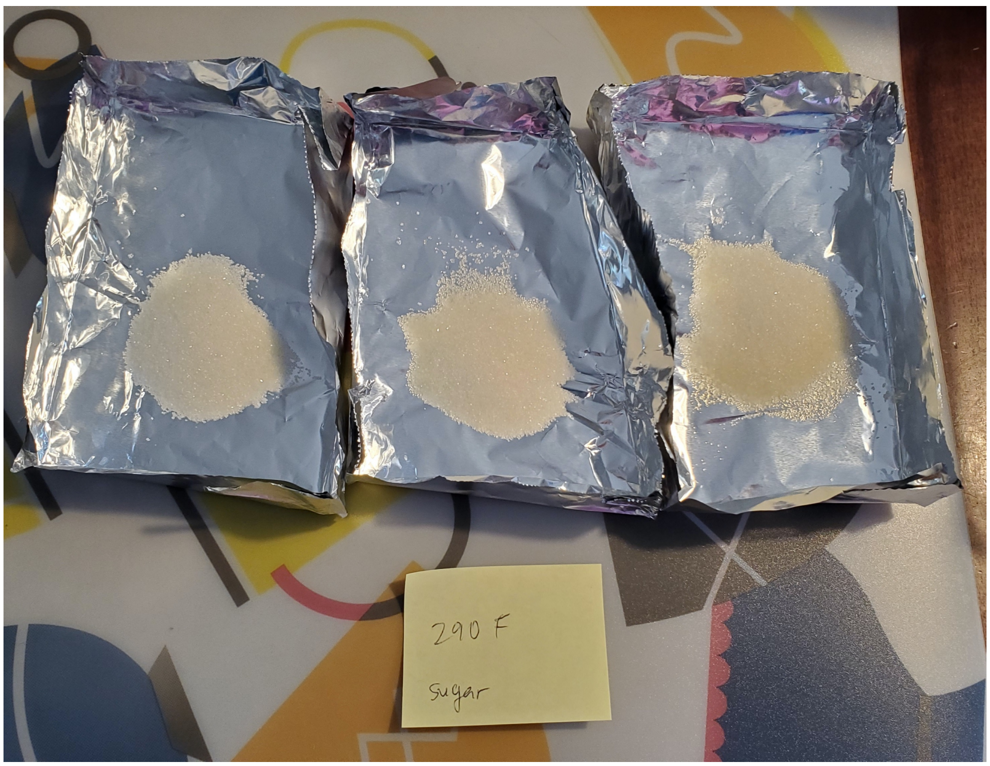

Figure 1: 3 replicates of sugar in the over at 290F dial temperature. The left sugar sample did not melt. The sugar samples in the middle and on the right melted along the edges of the sugar pile.

For the treatment groups (coconut sugar, erythritol sweetener and xylitol sweetener), a similar procedure was completed. With three replicates of a specific treatment in the oven at a time, the project started at 295F and increased or decreased the temperature depending on which scenario (A or B) was obtained. This was continued until the lowest temperature at which each respective alternative sugar or sweetener melted was found.

Calculation of the calibration temperature difference was the melting point of sugar (367F) minus the dial temperature at which sugar (control) had melted. The calibration temperature differences of the three replicates were averaged and used in melting temperature calculations of the three alternative sugars and sweeteners. The average calibration temperature difference was a positive number, which meant the oven was running hot – the dial temperature value reflected a higher actual temperature than stated. Since the oven was running hot, the actual melting temperature was calculated as the dial temperature plus the average calibration temperature difference. The following is an example of the melting temperature calculation:

Known: Dial temperature = 280 F   Average calibration temperature difference = 75 F

Melting temperature (actual) = Dial temperature + Average calibration temperature difference

$$= 280\ F + 75\ F = 355\ F$$

Microsoft Excel was used to compile and analyze data. Additionally, GraphPad Prism software was used for statistical analysis and the generation of graphs. The mean/average of the melting temperature of three replicates of each treatment group was determined and graphed. Standard deviation of each treatment group was also calculated.

Results

When sugar melted, it turned into a yellow liquid. The three replicates of sugar used for oven calibration melted at 295F, 290F and 290F. When these values were subtracted from the known melting temperature of sugar of 367F, this yielded calibration temperature differences of 72F, 77F and 77F. The average calibration temperature difference was 75F.

Melted coconut sugar turned into a dark brown liquid. Melted erythritol sweetener turned into a clear liquid. However, after melted erythritol was left in room temperature for a while, it recrystalized and formed a white solid as it was cooling down. Melted xylitol sweetener turned into a clear liquid. The average melting temperatures in Fahrenheit of the three treatments are shown in Figure 2. Coconut sugar had an average melting temperature of 355F for a sample size of 3 sugar boats. Erythritol sweetener had an average melting temperature of 250F for a sample size of 3 sugar boats. Xylitol sweetener had an average melting temperature of 200F for a sample size of 3 sugar boats. Average melting temperatures were reported to the nearest whole number because original raw data was reported to whole numbers. Only whole numbers would be considered significant due to the units of the oven dial in the first place. In addition, the standard deviation was 0F for all three alternative sugars and sweeteners.

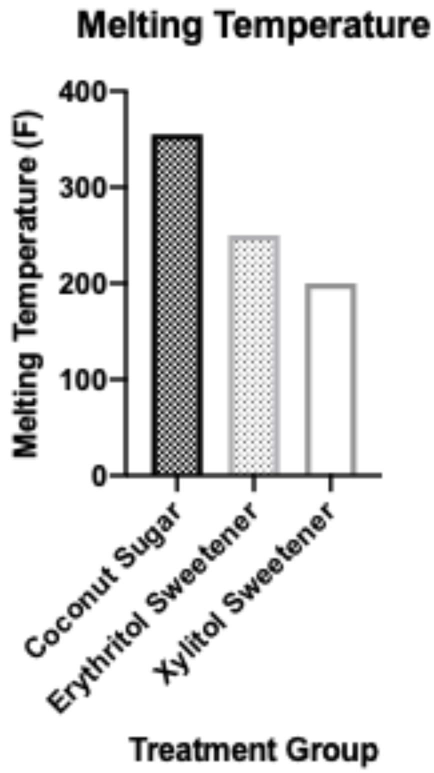

Figure 2: Graph of Average Melting Temperatures of the three treatment groups. The number of replicates/samples in each treatment was 3. Total sample size was 9 sugar boat samples.

Discussion

Average melting temperature for coconut sugar, erythritol and xylitol sweetener were 355F, 250F and 200F respectively. Alternative sugars and sweeteners had lower melting points than sugar. The melting temperatures obtained were consistent with what others have found. A characteristic of coconut sugar is having a very low melting temperature (Coconut sugar, 2016). In addition, coconut sugar is less processed and burns at a lower temperature than regular sugar (Salkeld, 2007). The melting temperature for coconut sugar that was obtained in this project, 355F, is compatible with what others found. The melting temperature for erythritol sweetener was 250F, which corresponds very closely to other scientists. Erythritol has a melting point of 121.5C (Showing metabocard for Erythritol, 2006). This is equivalent to 250.7F, which is only 0.7C higher than my results, which indicates the project was quite accurate in melting temperature determination. The melting temperature for xylitol sweetener was 200F, which is similar to others' data. Xylitol has a melting point of 93.5C (Showing metabocard for D-Xylitol, 2006). This is equivalent to 200.3F, which is only 0.3C higher than what this project obtained, which reflects accuracy in melting temperature determination. This suggests that using the known melting temperature of sugar to calibrate the oven was an effective method to calibrate the oven and make adjustments accordingly for the melting temperature results for the alternative sugars and sweeteners. There was a high similarity with the literature values, which verified and confirmed the validity of the data acquired.

The alternative sugars and sweeteners tested all had their own unique melting temperatures, due to each of them having their own physical properties and composition. Erythritol and xylitol sweeteners are sugar alcohols that come from plants, which may explain their lower melting temperature to some degree.

All three treatment groups had standard deviation of 0F, which suggested there was no variance within each group. Since there was no standard deviation, analysis of data was limited and did not allow further statistical analyses to be conducted. The constant temperature value obtained from the three replicates of each group reflects an intrinsic property of the respective alternative sugars and sweeteners. It is a property that cannot be altered transiently or easily. Melting point temperature is a stable and consistent property that does not change.

It was interesting to note that for the three sugar replicates for oven calibration, one sample melted at 295F, while the other two samples melted at 290F. As melting temperature is a stable property of the substance, this difference may be due to the location the sugar boat in the oven. Oven circulation may not be perfect, and one side of the oven may be hotter than other sides, which would cause one sugar sample to melt at a higher temperature than the other two.

This project worked well and allowed meeting the objective, however, it was not perfect. A source of error would be the guidelines of the oven dial. There were guidelines for increments of 25F, but since this project required adjusting in increments of 5F, the temperature control knob adjustments were estimated when a temperature between two guidelines was required. In this case, the temperature may not exactly be at the desired temperature. It would help if the oven temperature could be digitally adjusted to the appropriate temperature. Another source of error would be the height of the sugar or sweetener pile. One teaspoon of sugar or sweetener was placed in each aluminum boat, but the height of the sample was not the same, as some tended to spread out more. The difference in height affects qualitative results, but not quantitative data. It would affect to what extent each sample melted. For instance, it would affect whether the whole sample turned into liquid completely or only the top layer with some unmelted sugar on the bottom. However, this would not affect quantitative data as this project counted melting when even the edges were melted. The extent of melting did not matter for quantitative, melting point determination.

Conclusion

In this study, the oven temperature calibration with sugar allowed accurate determination of the melting point temperature of different alternative sugars and sweeteners. Using oven calibration data permitted calculating actual melting temperatures based on the oven dial temperatures. The prediction that melting temperature determination of alternative sugars and sweeteners would be possible based on the sugar calibration was observed. There was no variance within each treatment group, suggesting melting temperatures of each alternative sugar or sweetener remain constant. A limitation of this study was adjusting the oven dial temperature by 5F each time. If a smaller interval was adjusted when close to the melting temperature, this would provide a more accurate temperature of the true melting temperature of various alternative sugars and sweeteners. Also, placing a digital thermometer inside the oven would provide a temperature check to verify calculated melting temperatures, based on the initial sugar calibration, were in fact the temperatures that were actually inside the oven during melting. Future study investigating melting sugar temperatures of alternative sugars and sweeteners could include a greater variety of alternative sugar/sweetener samples in addition to adjusting smaller temperature intervals and including a digital thermometer.

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Appendix

Group	Sugar		
	1	2	3
Dial Tempterature	295	290	290
Actual Temperature	367	367	367
Calculated Temperature Difference	72	77	77
Average Calculated Temperature Difference	75		

Calculations of sugar dial and actual temperature to determine the average calculated temperature difference for subsequent calibration for the treatment sugars.

Group	Sugar			Coconut sugar			Erythritol Sweetener			Xylitol Sweetener		
	1	2	3	1	2	3	1	2	3	1	2	3
Dial Tempterature	295	290	290	280	280	280	175	175	175	125	125	125
Actual Temperature	367	367	367	355	355	355	250	250	250	200	200	200

Dial and actual temperature of sugar and alternative sugars. Dial temperatures of coconut sugar, erythritol sweetener and xylitol sweetener are raw values. Actual temperatures of coconut sugar, erythritol sweetener and xylitol sweetener were calculated with the average calculated temperature difference.

Group	Coconut sugar			Erythritol Sweetener			Xylitol Sweetener		
	1	2	3	1	2	3	1	2	3
Determined Melting Temperature	355	355	355	250	250	250	200	200	200
Average Melting Temperature	355			250			200		
SD Melting Temperature	0			0			0		

The determined melting temperatures of coconut sugar, erythritol sweetener and xylitol sweetener were averaged, to produce an average melting temperature for each respective group. Standard deviation of the determined melting temperature was also calculated for each treatment group.