

Research Article

Analyzing and Reporting the Physics of Chewing Gum and Its Impact on Dental Health Using Differential Scanning Calorimetry (DSC) and Logger Pro

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Abstract

In this research, we report on physics, chemistry, materials science and dental health implications of chewing gum. A small amount of Juicy Fruit chewing gum was analyzed using Differential Scanning Calorimetry (DSC) to study the effects of heating and cooling. The gum was subjected to thermal cycles between 0°C and 100°C at different ramp rates. The results revealed distinct phase transitions as the gum was heated and cooled. Initially, the gum was a soft solid, but upon heating, it became sticky, stretchy and rubbery, indicating a glass transition from a soft solid to a rubbery solid. This transition is analogous to the softening of gum when chewed in the mouth. With further heating, a melting transition occurred, representing the melting of additives within the gum, similar to their behavior during extended chewing. Cooling revealed a partial crystallization process, indicating that the heated rubbery gum transitioned into a partially ordered, crystallized state. Overall, these findings demonstrate that gum undergoes three distinct transitions, both in DSC and during chewing: glass transition, melting and crystallization. A detailed analysis of the DSC data, conducted using Logger Pro, reveals thermal energy patterns comparable to those experienced during the heating and cooling processes in the human mouth. This thermal behavior extends beyond physics and chemistry, providing insights relevant to dental health. Specifically, it has implications for the prevention of cavities, reduction of gum disease, improvement of bad breath and mitigation of hypomineralization, where each transition in the gum plays a vital role.

Keywords: Chewing Gum; Differential Scanning Calorimetry (DSC); Physics; Chemistry; Data Analysis; Logger Pro; Excel; Heating and Cooling; Ramp Rates; Glass Transition; Rubbery State; Enthalpy; Endothermic and Exothermic; Heat Flow; Specific Heat Capacity; Temperature; Dentistry; Dental Health; Teeth; Sugar; Dental Hygiene

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Introduction

Chewing gum is a soft, cohesive confectionery that is typically viewed as a harmless habit. It is composed of a mixture of resins, waxes and polymers. Most gums contain sweeteners such as fruit flavors and come in a variety of colors, shapes and sizes [1]. If one is an avid gum chewer, they may wonder how this piece of stiff candy transforms within seconds of chewing into a rubbery, sticky substance. Before chewing, gum contains water-soluble ingredients, such as flavors, sweeteners and colors, along with hydrophobic components, including waxes, resins and polymers. When the gum enters the oral cavity, its hydrophilic components are released and interact with saliva, while the hydrophobic components remain intact within the gum. Additionally, because the mouth is relatively warm (around 37 °C), the polymeric base of the gum softens, making it less stiff and stickier [2].

Chewing gum offers several advantages, such as stimulating saliva to aid digestion, providing muscular exercise for the jaws, gums and mouth, preventing cavities when sugar-free gum contains Xylitol (which reduces plaque and the buildup of food and <https://doi.org/10.46889/JDHOR.2025.6306> <https://athenaumpub.com/journal-of-dental-health-and-oral-research/>

bacteria) and providing cognitive benefits such as enhancing memory [1,3]. According to the American Dental Association (ADA), chewing sugar-free gum stimulates salivary flow through both mechanical action and taste receptor stimulation, which helps neutralize plaque acids and promotes enamel remineralization [4]. One study showed that sugar-free gum may help decrease molar incisor hypomineralization or tooth discoloration, in children [5]. However, if the gum contains sugar, it may do more harm than good. Instead of preventing cavities, it can promote bacterial growth, leading to dental decay and more complex oral health issues. Additionally, excessive gum chewing may result in jaw problems, including muscle strain or even Temporomandibular Joint (TMJ) dysfunction.

This research aims to understand the physics and chemistry behind Wrigley's Juicy Fruit chewing gum and connect it to dental health. The purpose of this experiment is to examine how the physical and chemical properties of chewing gum change before and after chewing. Specifically, the state of the gum will be observed and analyzed using heating and cooling cycles in Differential Scanning Calorimetry (DSC). The data collected will then be analyzed more thoroughly using Logger Pro to identify the types of transitions the gum undergoes during heating and cooling.

DSC is a thermo-analytical technique that measures the difference in the amount of heat required to increase the temperature of a sample and a reference [6]. This tool provides valuable insight into the thermal properties of different materials, such as polymers, plastics and resins. It is widely used for research and quality control in pharmaceutical, medical, dental and food sciences, as well as in pure and applied sciences. A variety of published articles that utilized DSC for research in material science are listed below [7-14]. Logger Pro, an analysis software, will be used to interpret the data collected by DSC. This software is designed to allow easy collection, display and analysis of data in scientific fields. It includes features such as graphs, tables, histograms and analysis tools (e.g., integrals) to display data [15]. Some articles that used Logger Pro for research are also referenced below [16-17]. In short, this research focuses on detailed results and data analysis of chewing gum using the DSC technique and Logger Pro to determine how many types of transitions gum undergoes during heating and cooling, which can be compared to the chewing process in the mouth. Chewing gum in the mouth increases its thermal energy and once chewing is stopped, the gum cools down. The speed of chewing can be compared to the ramp rate of heating and cooling in DSC. Therefore, another focus of this paper is on how the ramp rate of heating and cooling affects the nature of chewing gum in terms of its physics, chemistry and material science properties and how this might affect gum health as well. All results are presented in detail in the following sections: Theory (formulas used for analysis), Method (steps of operation), Material (details of the gum sample), Results (graphs plotted and analyzed with Logger Pro) and Discussion (the importance of the results to real-world applications of gum).

Theory

A. Theory of Chewing Gum

In this research, chewing gum was analyzed before and after chewing. When the chewing gum was taken out of its wrapper, it was in the shape of a rectangular prism; however, after it was chewed, the gum became a ball-like substance. As a result, the theory is divided into two sections:

(a) before chewing, (b) after chewing.

In the equations below, L = length, W = width, t = thickness of chewing gum strips, d = diameter, r = radius of the chewed ball of gum, D = density, M = mass, V = volume and S = surface area.

(a) *Before chewing the gum:*

$$\text{Total Surface Area (SA) of the gum (cm}^2\text{)} = (L \times W \times 2) + (W \times t \times 2) + (t \times L \times 2) \quad (1)$$

$$\text{Volume (V) of the gum (cm}^3\text{)} = L \times W \times t \quad (2)$$

$$\text{Density (D) of the gum (g/cm}^3\text{)} = \text{mass of the gum (m)} / \text{volume of the gum (V)} \quad (3)$$

(b) *After chewing the gum, you have a ball of chewed gum that is made of two gum strips*

$$\text{Surface Area of the gum ball (cm}^2\text{)} = 4\pi r^2 \quad (4)$$

$$\text{Volume of the gum ball (cm}^3\text{)} = V = \frac{4}{3} \times \pi r^3 \quad (5)$$

$$\text{Density of the gum (g/cm}^3\text{)} = \text{mass of the gum (m)} / \text{volume of the gum (V)} \quad (6)$$

B. DSC Theory for the Gum

According to thermodynamics, the heat (Q) can be related to mass (m), specific heat capacity of the sample (C_p) and change in temperature (ΔT) as shown in equation 7. Since DSC measures heat flow instead of just heat, the heat flow (dQ/dt) can be shown as a function of heating or ramp rate (dT/dt) in equation 9. The enthalpy or the area under the curve, is portrayed as dH .

$Q = m \cdot c \cdot \Delta T$	(7)
$Q / m = c \cdot \Delta T$	(8)
$dQ / dt = m \cdot c \cdot dT / dt$	(9)
$(dQ / dt) \cdot (1/m) = c \cdot dT / dt$	(10)
$C_p = ((dQ/dt) \cdot (1/m)) / (dT / dt)$	(11)
$C_p = \text{Normalized } Q \times 6, [C_p = c]$	(12)
Enthalpy = Area under the curve = ΔH	(13)
$\Delta H = \int C_p dT$	(14)

Material and Methods

In this research, Juicy Fruit chewing gum was used as the experimental chewing gum. This chewing gum comes in strips that take the shape of rectangular prisms, as shown in Fig. 1,2. Before the gum was chewed, the length of the strip was 6.85 cm, its width was 1.7 cm and its thickness was 0.1 cm. As shown in Fig. 1, the chewing gum is composed of 2 g of carbohydrates, specifically sugars and an additional 2 g of added sugars. This type of chewing gum specifically is composed of gum base, softeners and potential allergens.



Figure 1: Chewing gum used for research, (a) Picture of the front side, (b) picture of the back side showing nutrition facts.



Figure 2: The chewing gum before and after chewing. The strip (left) is before the gum was chewed, while the ball (right) is after.

As seen in Fig. 2, the chewing gum is a soft solid before chewing, in the form of a stripe and it can be easily broken. However, when it is chewed, it loses its softness in terms of easy breaking and changes into a stretchy and sticky type of solid, like rubber. At this point, if you try to break it by hand, it cannot be broken. This behavior can be related to the molecular alignment in

chewing gum. The molecular formula of a typical chewing gum can be seen in Fig. 3, which is composed of multiple groups of atoms, molecules and chemical structures. To understand the behavior and states of chewing gum, Differential Scanning Calorimetry (DSC) was used.

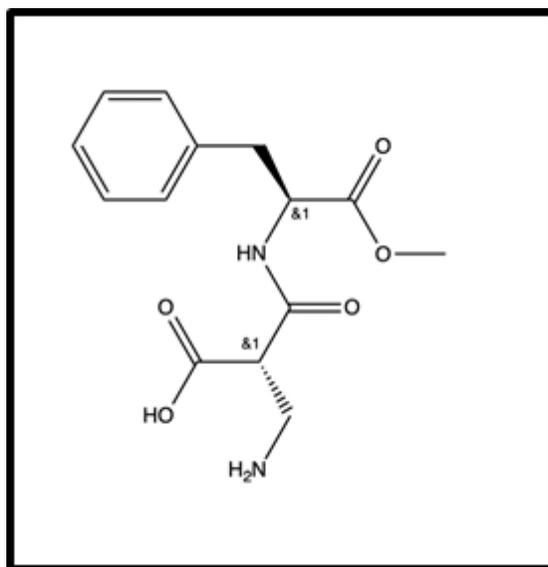


Figure 3: The molecular formula of chewing gum.

Fig. 3 depicts a representative molecular structure that can be found in components of chewing gum, showing distinct functional groups such as aromatic rings, carboxylic acids, esters and amides. The aromatic ring, which is only composed of C-C and C-H bonds, contributes to the hydrophobic gum base, influencing the rigidity and stability of the material, while the amide, carboxylic acid and ester groups can engage in hydrogen bonding or dipole-dipole interactions with polar components, such as the saliva in the mouth. These functional groups contribute to the gum's thermal behavior during DSC analysis, where transitions such as the glass transition, melting and partial crystallization reflect changes in molecular interactions.

DSC Experiments

The sample of the chewing gum was taken to a DSC for DSC experiments using a Differential Scanning Calorimetry (DSC) instrument from TA Instruments, model number MDSC 2920, in the Chemistry and Biochemistry Department of WPI, to study its various transitions. For these experiments, a small amount of the sample was loaded into pans and then sealed with lids using a DSC press and then placed inside a DSC instrument for heating and cooling. The heating was performed from 0°C to 100°C and then the sample was cooled from 100°C to 0°C at a constant heating and cooling rate. The experiments were repeated to check the reproducibility of results and it was found that the results are reproducible. The DSC experiments were repeated for four ramp rates: 10, 15, 20 and 25°C/min. The DSC instrument was calibrated before the start of each run of the experiments. The respective heat flow of the samples was recorded along with the temperature and time changes during the heating and cooling scans. All environmental and experimental conditions were kept identical for all runs so that a good comparison of the transitional parameters can be made to compare all samples.

Usually, typical matter has three states: solid, liquid and gas or two states from solid to liquid. However, chewing gum has more states within the solid state. So, our goal is to use DSC to explore and investigate the types of states of chewing gum within the solid state.

The data of the chewing gum was taken from DSC and analyzed using Logger Pro. The detailed analysis of chewing gum shows several hidden facts about the various states of chewing gum. The detailed results are shown in the form of data tables in the following section. Following the theory and equations that are shown in the Theory section, the following physical quantities are calculated: surface area, volume, density, normalized heat flow, specific heat capacity, enthalpy and thermal energy for chewing gum. The detailed results of the chewing gum can be seen in the Results section and the data details can be seen in the Data Table section.

Results

The chewing gum data was obtained using DSC and then plotted using Logger Pro. The detailed results of the chewing gum are shown below.

The DSC data that was obtained is plotted as temperature vs time in Fig. 4 to show how heat is changing in chewing gum when it is heated and cooled. The positive slope of the curve is the heating phase, while the negative slope is the cooling phase. The flat line on the graph shows DSC resting at 100°C. This data portrays how DSC heats and cools.

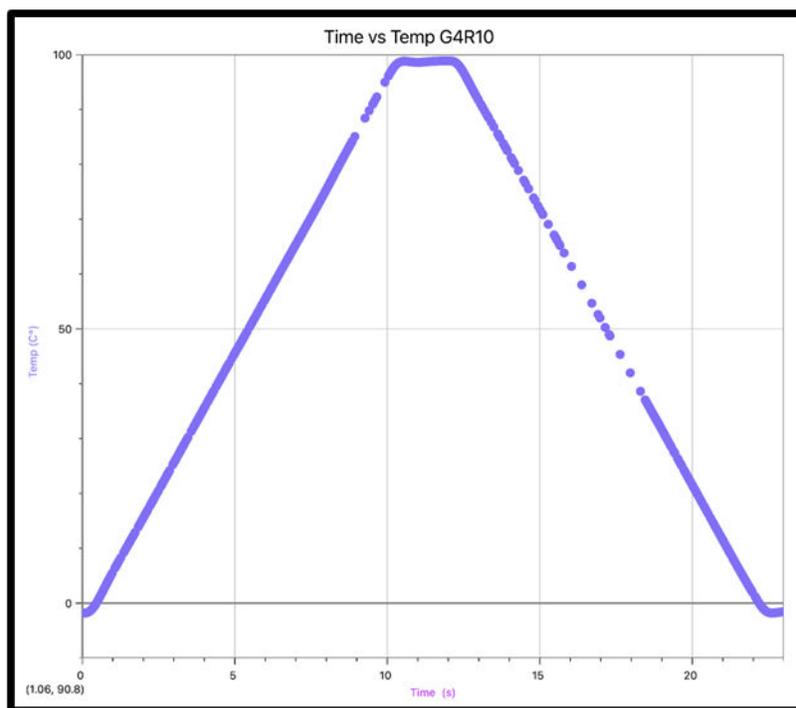


Figure 4: Temp vs Time for gum with ramp rate of 10°C/min.

Fig. 5 portrays the DSC plotted as Heat Flow vs Temperature to portray how heat is changing within the chewing gum as it is heated and cooled at a ramp rate of 10°C/min, while the graph below, Fig. 6, portrays the DSC plotted as Normalized Heat Flow vs Temperature to portray how heat is changing within the chewing gum as it is heated and cooled at ramp rate of 10°C/min. Fig. 6 is a more effective way of measuring heat flow as it is normalized by the weight, which means that the gum's weight does not affect the results.

Fig. 7 to 10 portray the changes in specific heat capacity of chewing gum as the temperature increases and decreases at different ramp rates. The shaded area in each figure represents the integral or the area under the curve, which indicates how much energy is absorbed by the chewing gum during the heating and cooling phases: Fig. 7: At a ramp rate of 10°C/min, the energy absorbed is 577.7 J/g·°C. Fig. 8: At a ramp rate of 15 °C/min, the energy absorbed is -149.7 J/g·°C. Fig. 9: At a ramp rate of 20°C/min, the energy absorbed is -487.6 J/g·°C. Fig. 10: At a ramp rate of 25 °C/min, the energy absorbed is -209.8 J/g·°C.

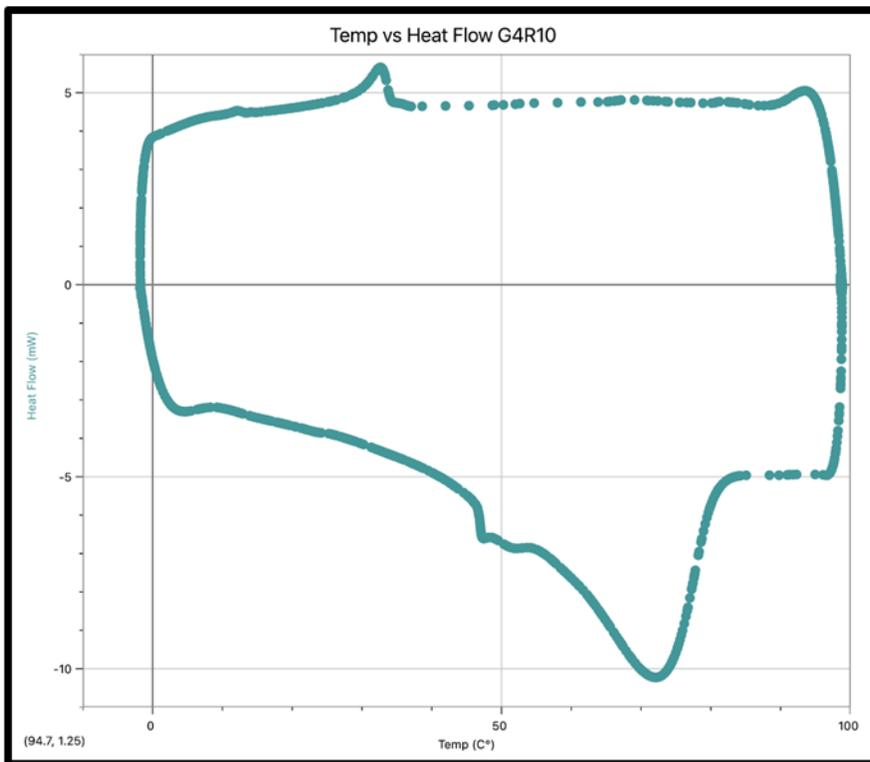


Figure 5: Heat flow vs temp plot for gum with ramp rate of 10°C/min.

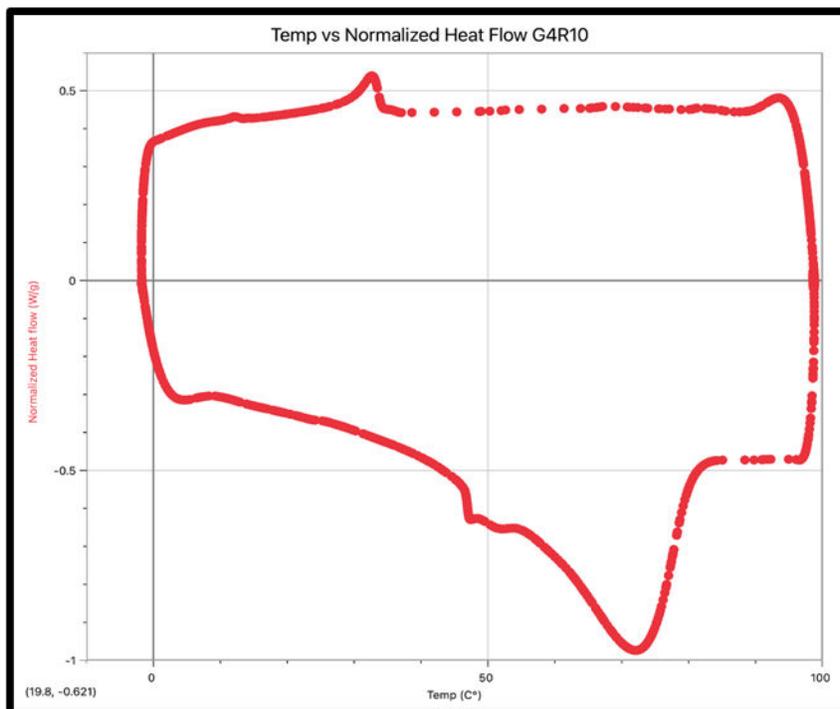


Figure 6: Normalized heat flow vs temp plot for gum with ramp rate of 10°C/min.

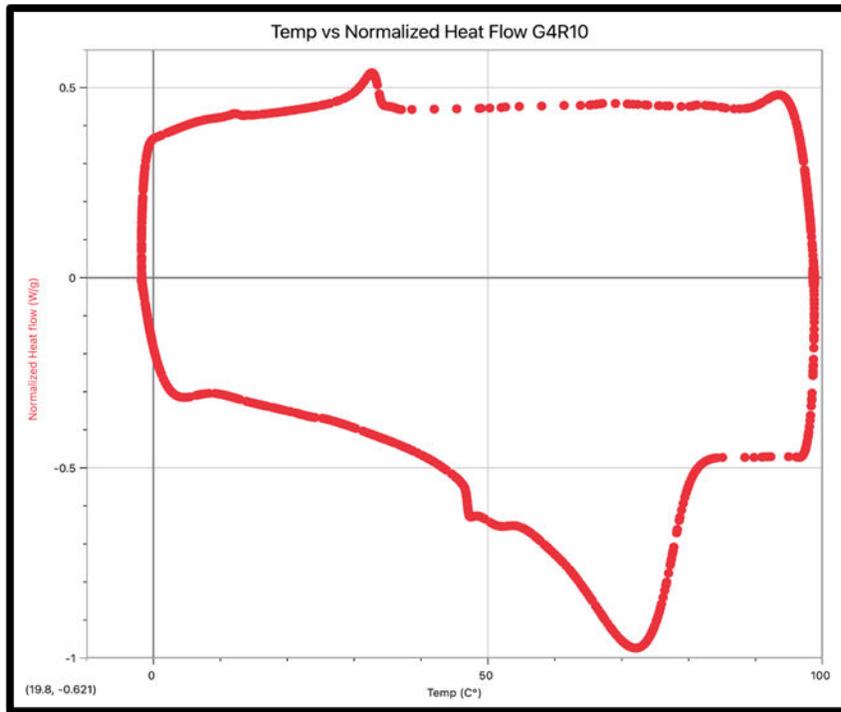


Figure 7: Cp vs temp plot for gum with ramp rate of 10°C/min.

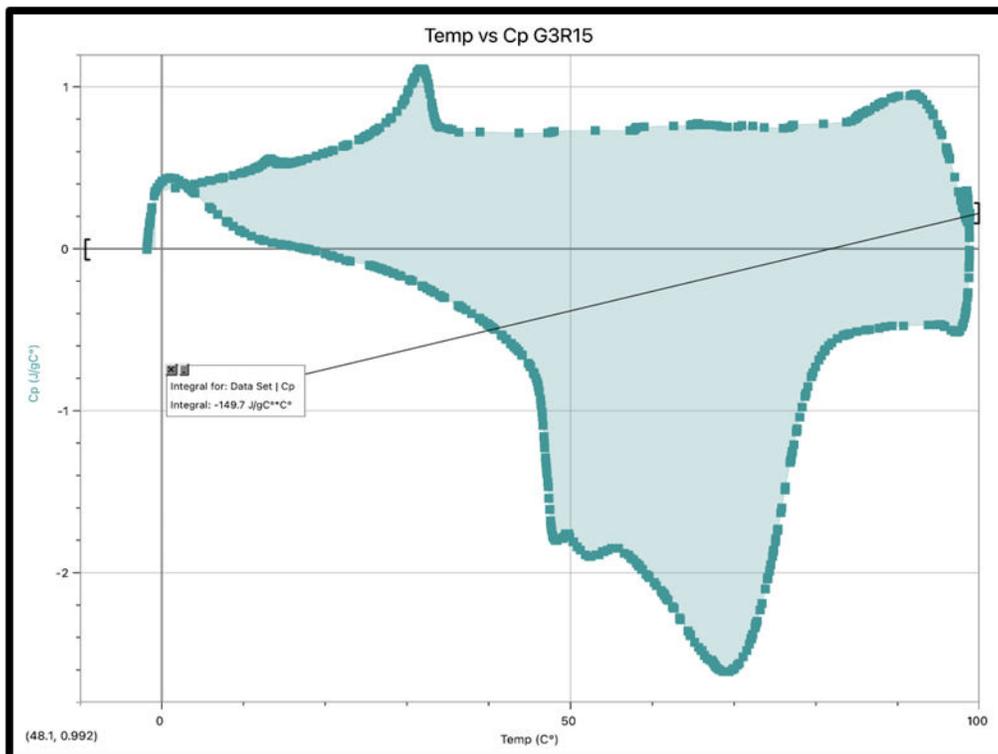


Figure 8: Cp vs. temp plot for gum with ramp rate of 15°C/min.

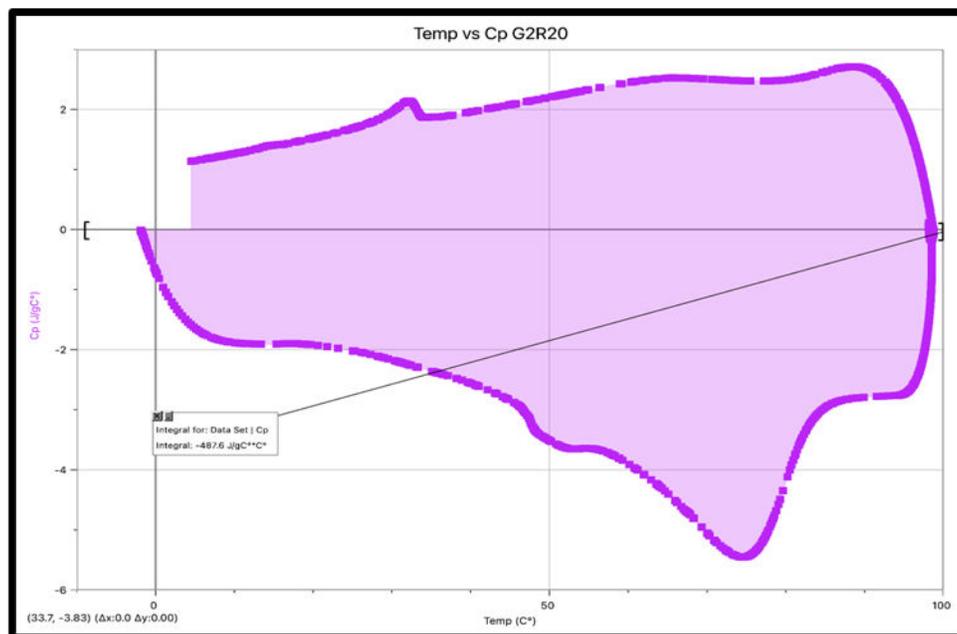


Figure 9: Cp vs temp plot for gum with ramp rate of 20°C/min.

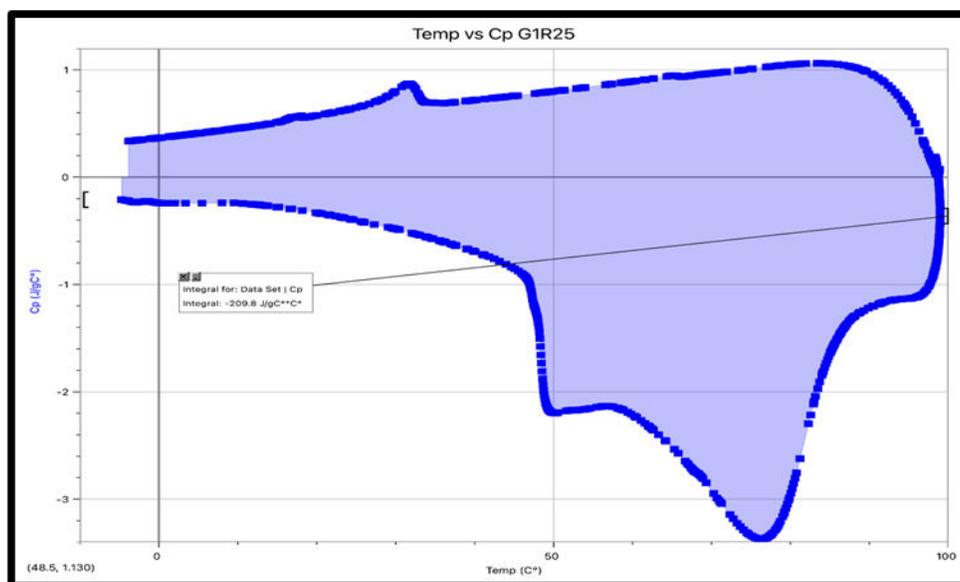


Figure 10: Cp vs temp plot for gum with ramp rate of 25°C/min.

Fig. 11 shows the specific heat capacity (C_p) of a chewing gum sample as a function of temperature plot for heating only using DSC. A glass transition is observed around 10-20 °C in the form of a small step, which indicates the softening of shapeless components such as the gum base. A broad endothermic region between 50-70 °C suggests the melting of crystalline constituents like sugars and waxes. The sharp increase in C_p above 90 °C may correspond to moisture loss.

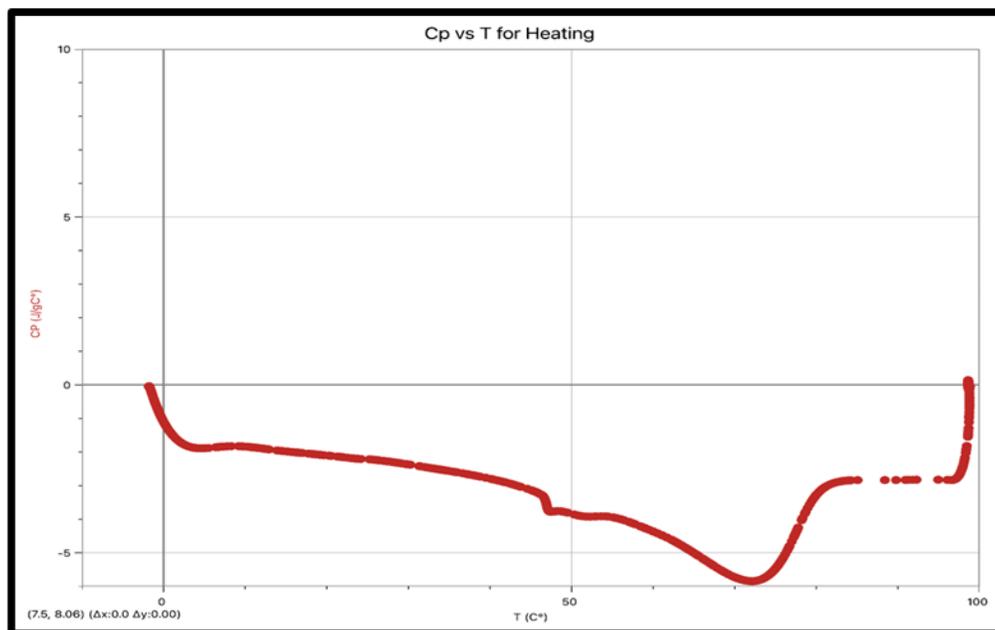


Figure 11: Specific Heat Capacity (C_p) vs Temperature plot for heating only with a $10^\circ\text{C}/\text{min}$ rate.

Fig. 12 shows the specific heat capacity (C_p) of a chewing gum sample as a function of temperature for cooling only using DSC. A noticeable rise in C_p near $\sim 20\text{-}30^\circ\text{C}$ may reflect the partial crystallization of left sugar and gum. A sharp decline in C_p below 10°C likely corresponds return to the glassy state.

Fig. 13-16 heating curve highlights the thermal events occurring between $\sim 25^\circ\text{C}$ and 95°C during the heating of chewing gum. These are zoomed-in parts of heating only to show each transition that occurred in the heating of gum along with the associated thermal energy in the form of enthalpy. The specific heat capacity (C_p) steadily decreases with increasing temperature, followed by multiple stepwise drops and a pronounced endothermic dip centered around 70°C . These features are likely associated with the sequential melting of crystalline sugar phases and softening of additives or waxes.

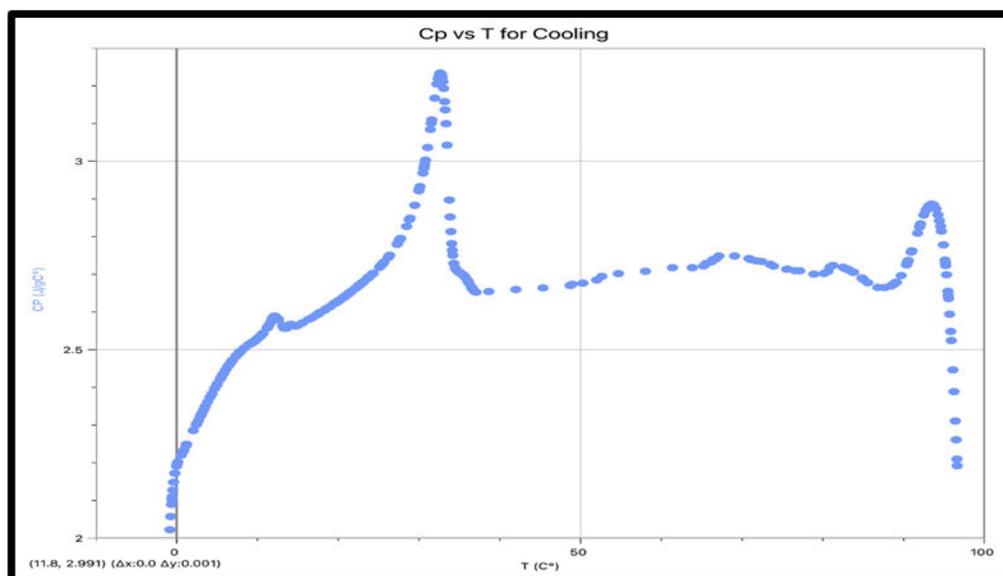


Figure 12: Specific Heat Capacity (C_p) vs Temperature plot for Cooling only with $10^\circ\text{C}/\text{min}$.

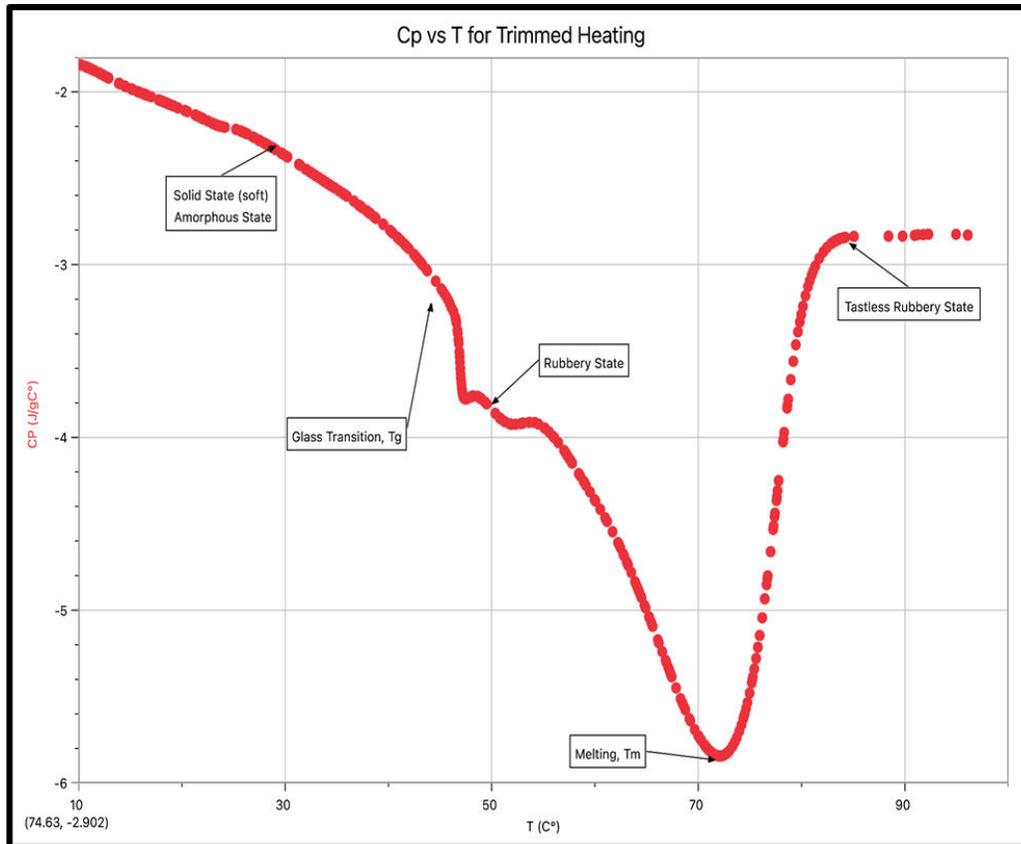


Figure 13: Zoomed-in plot for Heating only for chewing gum showing Cp vs T graph with details of all phases occurring in chewing gum during heating using DSC. Chewing gum stays in an Amorphous state initially before chewing. As it starts being chewed, it shows a jump in terms of Glass Transition and goes to a rubbery state. Then, when it is chewed more, it shows the melting of monomers like sugar in terms of a big dip, an endothermic downside peak and then becomes a tasteless, rubbery material.

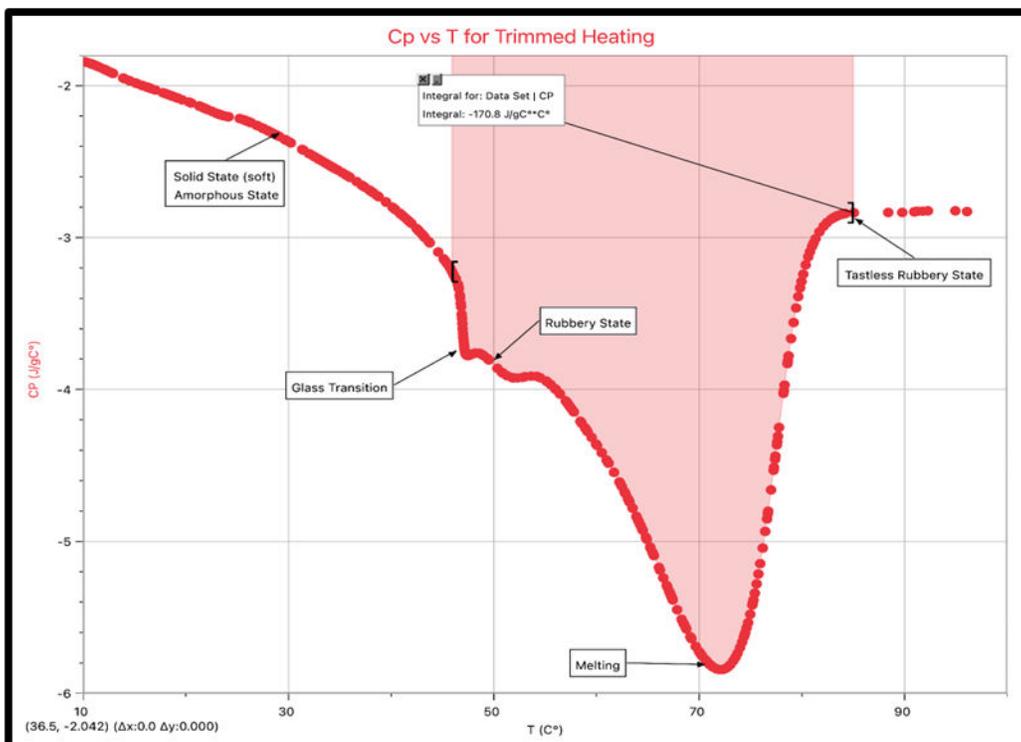


Figure 14: Cp vs Temperature portraying the amount of heat absorbed between the glass transition and tasteless rubbery state.

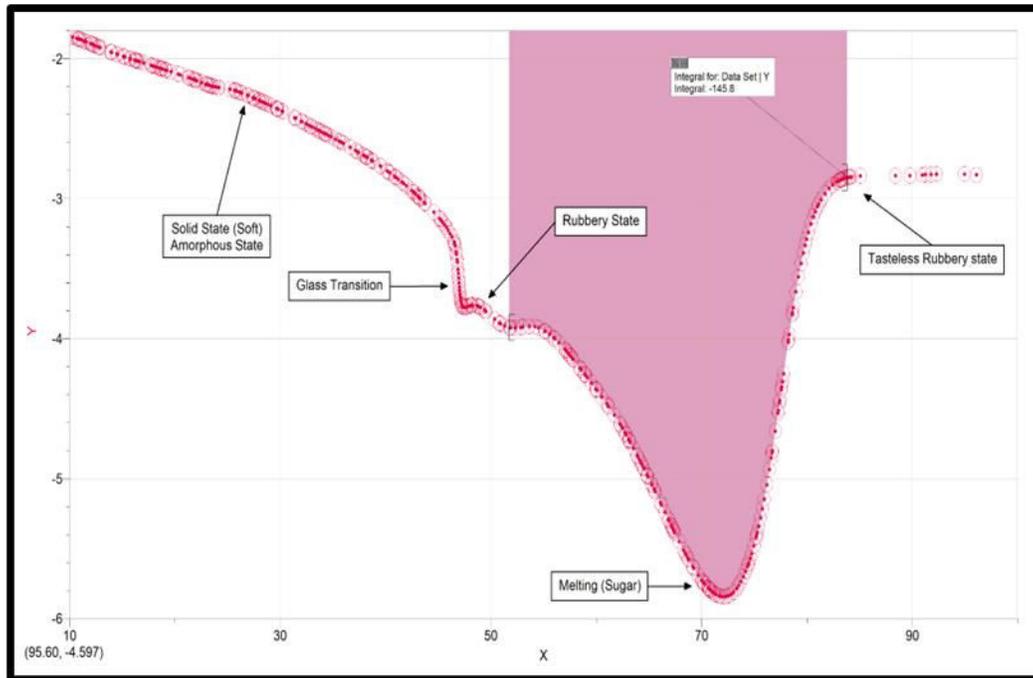


Figure 15: Trimmed DSC Heating Curve of Chewing Gum: C_p vs Temperature, portraying the amount of heat absorbed between the rubbery state and the tasteless rubbery state.

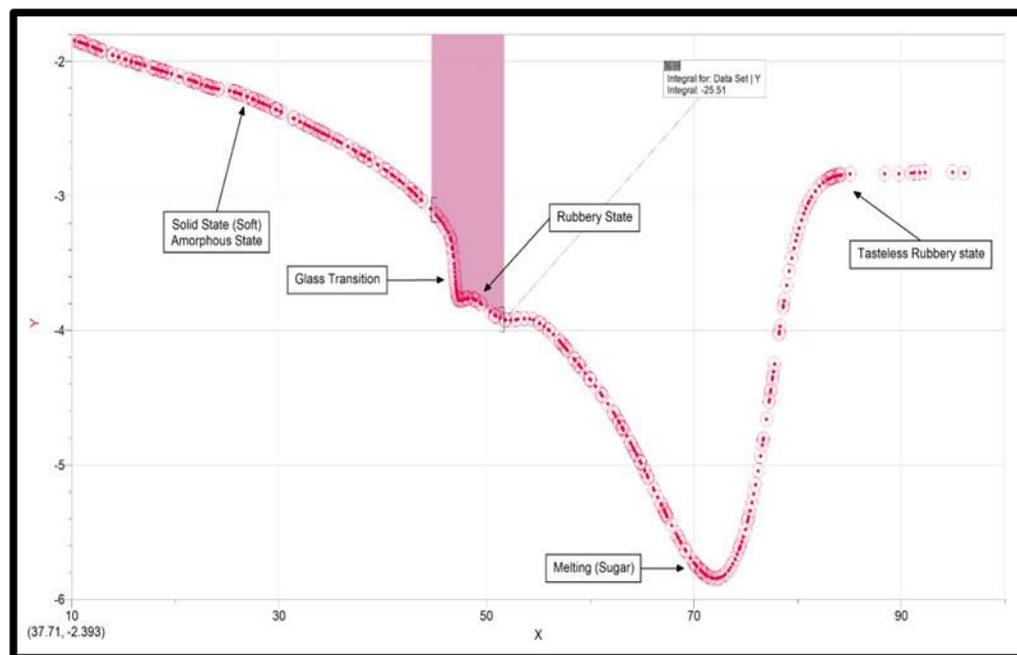


Figure 16: C_p vs Temperature portraying the amount of heat absorbed between the glass transition and the rubbery state.

Fig. 17,18 portray the zoomed-in part of the cooling curve that highlights the thermal events occurring between $\sim 95^\circ\text{C}$ and 5°C during the cooling of chewing gum. Fig. 17 shows how much total thermal heat is released while chewing gum is cooled for a full cooling process. The specific heat capacity (C_p) steadily varies and decreases for part of the scan with decreasing temperature, followed by multiple stepwise drops and a sharp peak, which is an exothermic peak and shows partial crystallization of monomers like left sugar and polymer that is chewing gum. While Fig. 18 shows how much thermal energy is released only in partial crystallization, that is a sharp upward peak.

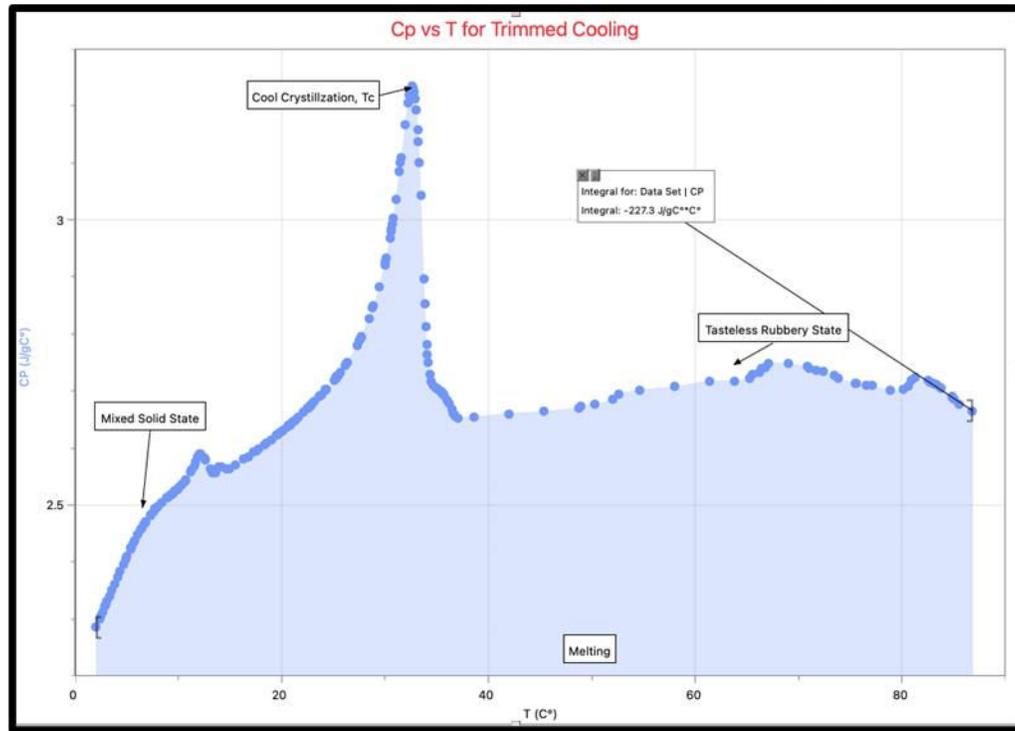


Figure 17: Zoomed-in DSC Curve for cooling only for Chewing Gum: Cp vs T: To show partial crystallization in terms of a sharp peak.

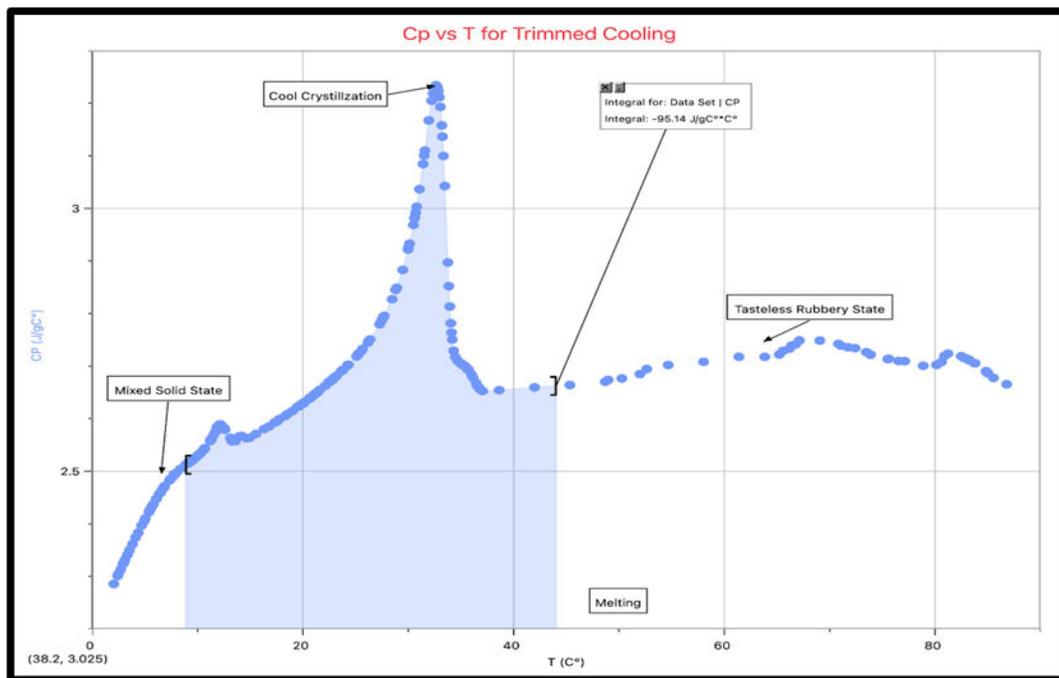


Figure 18: Cp vs Temperature portrays the amount of heat released between the mixed solid state and the tasteless rubbery state, involving partial crystallization in cooling.

Fig.19 is plotted as Cp vs time. It shows how time changes when the chewing gum is heated from 0-100°C, then cooled from 100-0°C with a ramp rate of 10°C/ min. It takes about 22 minutes to run the full heating and cooling cycles for the chewing gum. Chewing gum shows the glass transition and melting transition in heating, where the glass transition shows that the chewing gum state has changed from an amorphous state to a rubbery state. The melting transition shows that all the sugar, sucrose and the taste material that was added to chewing gum melted at this temperature and sugar and sucrose changed from a crystalline state to a liquid state. The zoomed-in part of Fig. 19 during the heating cycle can be seen in Fig. 20.

Fig. 19,20 both show details of the time event as a zoomed-in part of chewing gum during heating only. At what time glass transition starts, what time ends, how long glass transition take place, at what time does melting begin or end and when it is maximum, all these details can be found from these Fig. 21. All time details of each transition of gum are reported in the Table 8.

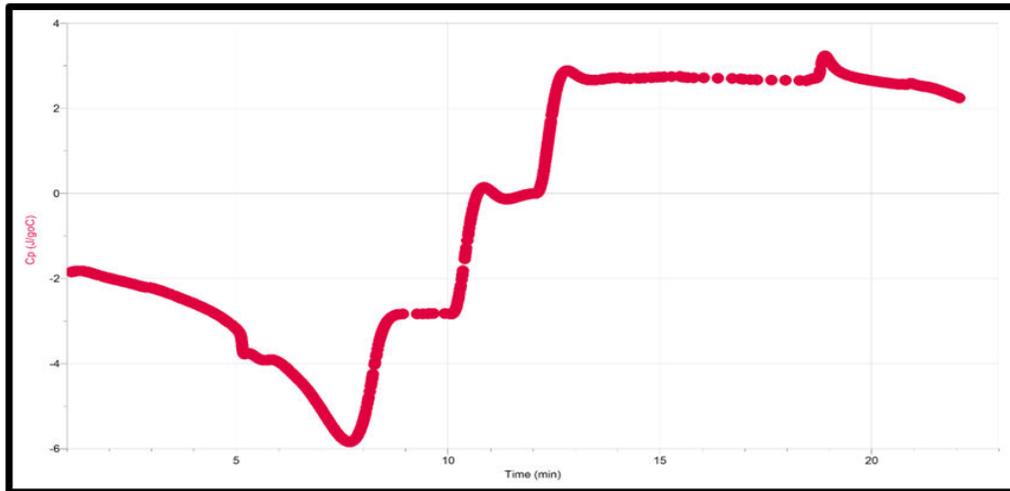


Figure 19: A full heat and cool graph plotted as C_p vs Time for chewing gum at a ramp $10^\circ\text{C}/\text{min}$ Rate.

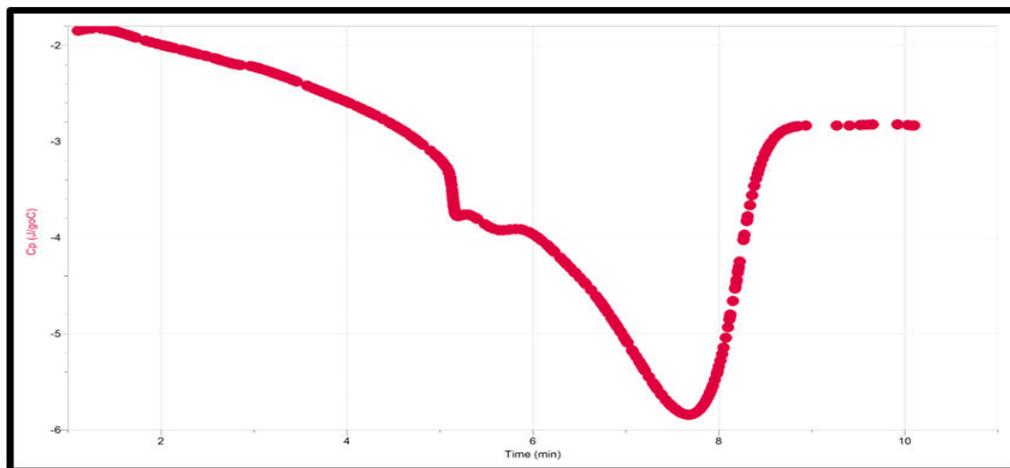


Figure 20: Zoomed in plot for full heating only, as C_p vs Time at ramp rate $10^\circ\text{C}/\text{min}$ to show how time is involved in the transitions that are taking place during heating in gum.

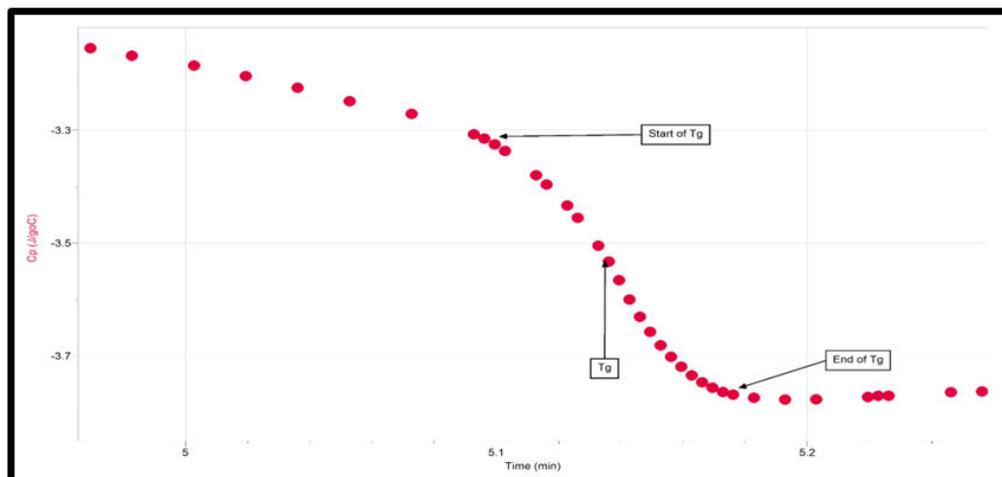


Figure 21: Zoomed in plot to show glass transition only during heating, as C_p vs Time at ramp rate $10^\circ\text{C}/\text{min}$ to show how time is involved in glass transition in gum.

Data Tables

Details of all data that are collected by DSC and Logger Pro graphs using theories used as mentioned in the theory section and the graphs shown in the result section, can be seen in the Table section below. Table 1 presents the data for the unchewed gum, while Table 2 shows the data for the chewed gum. Table 3 provides a comparison between the data in Tables 1 and 2. From Data Table 3, it can be seen clearly that after chewing the gum, the density increased, while the surface area, volume and mass decreased.

Length (cm)	6.85
Width (cm)	1.7
Thickness (cm)	0.1
Total SA (cm ²)	23.29
Volume (cm ³)	1.1645
Mass (g)	2.5
Density (g/cm ³)	0.95

Table 1: Data of unchewed gum.

Mass (g)	1.5
Diameter (cm)	1.2
Radius (cm)	0.6
Total SA (cm ²)	4.52
Volume (cm ³)	0.905
Density (g/cm ³)	1.29

Table 2. Data on chewed gum.

Difference in Density (g/cm ³)	+ 0.34
Difference in SA (cm ²)	- 20.48
Difference in mass (g)	- 1.0
Difference in volume (cm ³)	- 0.2595

Table 3: Comparison between unchewed and chewed.

Table 4 portrays the details of thermal energy trapped in the chewing gum between heating and cooling cycles of DSC at four different ramp rates. As the ramp rate increases, the trapped thermal energy decreases arbitrarily.

Ramp Rate (°C/min)	Thermal Energy (J/g)
10	577.7
15	149.7
20	487.6
25	209.8

Table 4: Thermal energy stored in chewing gum between heat and cool.

Table 5 shows the detailed results of the stored thermal energy within chewing gum during the heating cycle of DSC at a ramp rate of 10°C/min. The heating cycle indicates absorption of thermal energy, which is known as an endothermic reaction meaning thermal energy is entering the chewing gum as it is heated. As shown in Table 5, for the full heating cycle, the absorbed heat is 287.1 J/g. However, when the heating cycle is trimmed, the thermal energy absorbed decreases to approximately 170.8 J/g.

Part of the Transition	Thermal Energy (J/g)
Full heat and cool	577.7
Full heat	287.1
Trimmed heat	170.8
Glass Transition	25.51
Melting	145.8

Table 5: Thermal energy stored in chewing gum in heating for Ramp rate 10°C/min.

Table 6 shows the detailed results of the thermal energy released from chewing gum during the cooling cycle of DSC at a ramp rate of 10°C/min. The release of thermal energy is known as an exothermic reaction, meaning heat is being released from the chewing gum. The thermal energy released during trimmed cooling is less than that observed during the full cooling cycle.

Part of the Transition	Thermal Energy (J/g)
Full heat and cool	577.7
Full cool	227.3
Trimmed cool	95.14
Partial Crystallization	52.12

Table 6: Thermal energy released in chewing gum in cooling for Ramp rate 10°C/min.

Table 7 lists the onset, midpoint and end temperatures for the glass transition, melting and crystallization events, along with their associated Cp values. Negative Cp values during glass transition and melting indicate endothermic heat absorption, while positive Cp values during crystallization indicate exothermic heat release. Table 8 portrays the exact time details of each transition that occurs within the chewing gum at a ramp rate of 10.

Transition	T (°C)	Cp (J/g°C)
Beginning of Glass Transition	44.69	-3.094
Ending of Glass Transition	47.45	-3.757
Glass Transition, Tg	46.52	-3.31
Glass Transition Length	2.76	0.663
Beginning of Melting	53.63	-3.893
Melting, Tm	72.02	-5.887
Ending of Melting	82.74	-2.854
Beginning of Crystallization	38.58	2.664
Crystallization, Tc	32.58	3.247
Ending of Crystallization	20.29	2.642

Table 7: Details of specific heat capacity and temperature for various Transitions.

Transition	Time (min)
Beginning of Glass Transition	4.9
Ending of Glass Transition	5.12
Glass Transition Length	0.13
Glass Transition, Tg	5.1
Beginning of Melting	5.85
Melting, Tm	8.8
Ending of Melting	7.66

Table 8: Details of time for various Transitions.

Discussion

Juicy Fruit chewing gum was studied in detail in this research using DSC. The detailed data analysis was done using Logger Pro. Looking at all the research details that are portrayed in the sections above, such as theory, data tables and results, it is clearly seen that the chewing gum has a softer state in the beginning, but once it is chewed, it becomes rubberier and stretchier. This effect can be seen in terms of the glass transition in DSC results. The glass transition appears as a jump in the graph that is plotted between Specific Heat Capacity vs Temperature in heating. The jump was $0.663 \text{ J/g}^\circ\text{C}$ high while 2.76°C long. This jump is very significant and it has thermal energy associated with it as $25.51 \text{ J/g}^\circ\text{C}$, which represents how much thermal energy is absorbed when the chewing gum state has changed from a soft to a rubbery solid. The glass transition takes place from 44.0°C to 47.0°C , which is comparable to the body temperature to the body, mouth and friction temperature while the chewing gum is chewed in the mouth. So, these results are consistent with not only the DSC but also the mechanics of the human mouth. Furthermore, the melting transition that appeared in the DSC graph shows how sugar, resins, softeners and polymers melt at that state. That is why the big dip is a bigger endothermic transition in DSC, which clearly shows that the thermal energy absorbed is $145.8 \text{ J/g}^\circ\text{C}$. This melting occurs at 72°C in the DSC graph, which is representative of the temperature of the mouth with repetitive motion of chewing due to the added temperature from friction.

The glass transition is known as the gradual shift in amorphous polymers from a hard, brittle state to a rubbery soft state as temperature rises. The glass transition temperature, commonly referred to as T_g , is a key characteristic when selecting polymers for specific applications. It represents the temperature below which a plastic's physical properties shift to a rigid, glassy or semi-crystalline state. Above T_g , the material becomes soft and rubber-like, while below T_g , the molecular motion is greatly restricted, resulting in a stiff and brittle behavior. The glass transition temperature ultimately marks where this transition occurs. This value is typically lower than the melting temperature [17].

During cooling, we see a sharp but small exothermic peak, which is an indication of a release of thermal energy, which allows chewing gum to transition from the rubbery state to a partially ordered state or a partially crystalline state (T_c).

To explain the molecular arrangement, present in each type of transition that chewing gum has during heating and cooling, a model is depicted below in terms of Fig. 22,23. Chewing gum is a polymer that is a long-chain molecule forming a ribbon-like shape. When Chewing gum is in the original shape, not chewed, it stays in amorphous state forming soft solid that can be seen as (a) in Fig. 22 showing how polymers are staying in the disordered state forming ribbons unparallel to the entire structure, whereas when Chewing gum is chewed and go after glass transition, it goes to rubbery state which is stretchy state and polymer seems like stretched ribbons as shown in (b) of Fig. 22 during heating. When chewing gum continues to heat, since the polymer has already been stretched, now the taste, flavors, sugar molecules, which are monomers, start melting and show a big dip in the heating of DSC and all the sugar goes into the mouth, between teeth, etc. After heating, it can be seen as T_m in Fig. 23. When chewing gum is cooled or we stop chewing and take it out of the mouth, the chewing gum goes into a cooling state and shows a partial crystallization in the form of partially crystalline ribbons of polymer, as shown in (c) of Fig. 22. Whereas the melting and partial crystallization of Monomers like sugar can be seen in Fig.23.

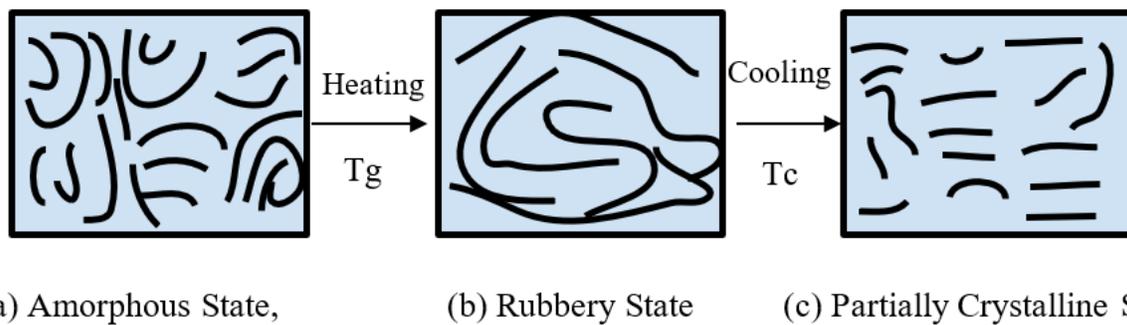


Figure 22: Depiction of the Model of the Chewing Gum (Polymer) for three states during heating and cooling.

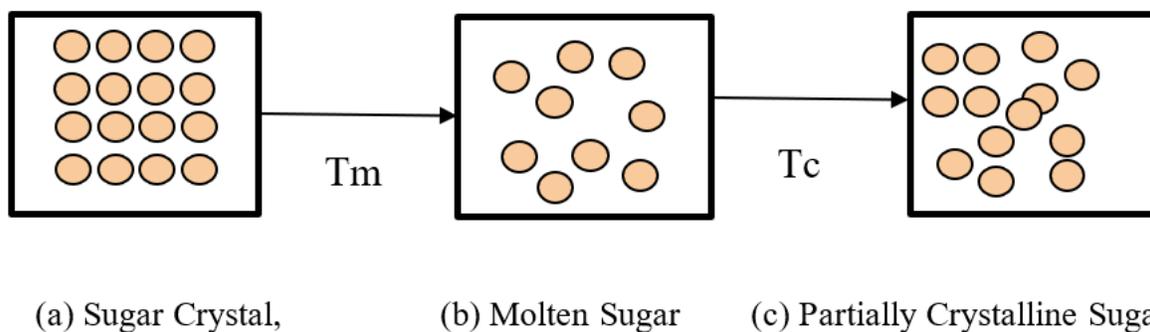


Figure 23: Depiction of the Model of the melting of Sugar and Sucrose present in chewing gum during the heating and cooling or chewing process.

From a dental health perspective, the thermal and physical transitions observed throughout this research are highly relevant. The glass transition observed in the gum explains why gum becomes softer and easier to chew in the mouth, which stimulates salivary flow. Increased saliva production is beneficial because it neutralizes plaque acids, washes away food particles and supports enamel remineralization, all of which help prevent cavities. The melting transition corresponds to the release of flavors and sweeteners, which can provide either positive or negative health effects depending on whether the gum is sugar-free. Sugar-free gums with Xylitol help reduce bacterial growth, while sugar-containing gums promote plaque formation and tooth decay. The partial crystallization observed during cooling represents the gum regaining some structure, which parallels what happens when chewing stops. This change may influence how long the gum can be chewed without breaking down completely, which is important for its effectiveness in maintaining salivary stimulation over time and its impact on TMJ.

Conclusion

The objective of this research was to study the physical and chemical properties of chewing gum throughout the process of chewing. Chewing gum was observed through heating and cooling cycles between 0°C to 100°C with four different ramp rates of 10, 15, 20 and 25°C/min. using DSC. Logger Pro was then used for detailed data analysis to find details of transitions that occurred in chewing gum during heating and cooling. The DSC showed clear thermal transitions in chewing gum. During the heating phase, a glass transition occurred in terms of a step, which portrays the soft chewing gum becoming more like a rubbery solid. This is analogous to gum softening in the mouth. Next up is the melting transition, which portrays the melting of additives, sweeteners and softeners in the gum, appearing in terms of a big dip. During cooling, a partial crystallization occurred in terms of a small peak, which leads to a more ordered gum state. After the gum was chewed, its density increased by 0.34 g/cm³, whereas the surface area decreased by 20.48 cm², the mass decreased by 1.0 g and the volume decreased by 0.26 cm³. This change is ultimately due to the chewing gum transitioning to the rubbery state, which is denser and contains fewer preservatives and sweeteners. When chewing gum was heated and cooled with different ramp rates, the thermal energy involved in the glass transition decreased. The thermal energy involved in glass transition is 25.51 J/g, in melting 145.8 J/g, for complete heating 287.1 J/g and for partial crystallization 51.12 J/g. All these numbers correspond to the 10°C ramp rate. The glass transition appears around 46°C, whereas the melting point appears around 72°C and the crystallization occurs around 32°C. The glass transition occurs around the 5-minute mark, while the melting occurs around the 8-minute mark. The results above portray the significance of the phase changes that occur when chewing gum is heated and cooled. The ramp rates can be analogous to the speed of chewing and the amount of time the chewing gum is chewed.

This knowledge about chewing gum can be used in the dental field to help prevent cavities, hypomineralization and bad breath odor. For example, dentists may now know how long chewing gum needs to be chewed for xylitol (good for preventing caries) to be released in the mouth. This data guides dentists in understanding the phases within the chewing gum and how that impacts dental health. This research is not only critical for dental-related research but also can be used in other fields such as physics, chemistry and may have other real-life applications.

Conflict of Interest

There are no conflicts of interest that may have influenced the research, authorship or publication of the article.

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