Why “Melted Cheese” Isn’t Really Melted

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Introduction and Materials

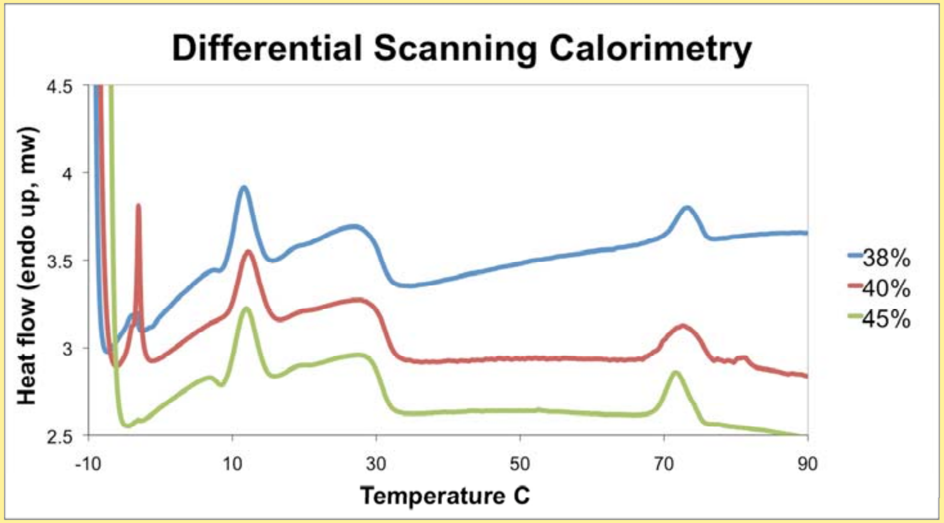
Contrary to what is commonly called “melting”, cheese actually does not undergo a melting process. Instead, cheese undergoes what is called a “glass transition”. At or below the glass transition temperature T_g, or brittle-ductile temperature T_b, the cheese exhibits a hard, or “glassy” state. Above these temperatures, it turns into a “rubbery” solid that flows easily. Tests on the physical properties of American process cheese were performed to evaluate these temperatures (T_b and T_g) and this flow as a function of cheese moisture content. Samples of three different moisture contents were tested to find the brittle-ductile temperature (the temperature at which the cheese yields gradually as opposed to breaking in a brittle manner due to heating or increased moisture content) by the 3-point bend test, the extent to which the samples flow under gravity when heated to 100° C by the Schreiber test, and the glass transition temperature by differential scanning calorimetry (DSC).

The American process cheese samples were made to compare some of cheese’s physical properties at three different moisture levels: 38%, 40% and 45% moisture. To make the samples, aged and young cheddar, dry whey powder, trisodium phosphate (emulsifier), and water were combined in specific ratios to make the desired moisture percentage. These ingredients were mixed and heated to 80° C in a dual-screw process cheese cooker using indirect steam heat. The samples were packaged in 0.9 kg containers with self-sealing plastic liners, and were kept at refrigerator temperature until tested.

Differential Scanning Calorimetry

The cheeses were brought to room temperature, and small samples (20-25 mg of each moisture content) were sealed into DSC pans. Scanning for endothermic flow into the cheese was performed from -40° to 120° C to determine T_g.

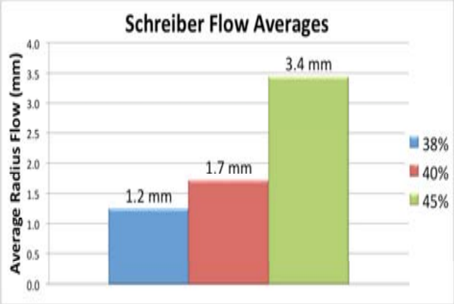
Results: There is no signature peak of a glass transition within the expected range, but a sharp peak is clear for melting of solid water on the left end of the graph. The activity from 10° to about 30° C is characteristic of lipid melting, and the peak at about 70° C is from denaturation of whey protein.



Schreiber Test

Small, uniform discs were placed in the center of a Schreiber concentric circle array and heated for 10 minutes at 100° C. If heating continued longer than about 10 minutes, there would be little difference in flow distance for each sample during that time, and greater evaporation from prolonged heating would hinder accurate results, so it is unnecessary to consider time longer than 10 minutes (Park, Rosenau, and Peleg 1984). Due to heating and glass transition, the cheese flowed outward under the force of gravity. The distance of flow for each sample was measured along 8 linear axes orthogonal to the concentric circles. The average of these measurements is the overall outward flow of the sample. Five duplicates were taken for each moisture content.

Results:

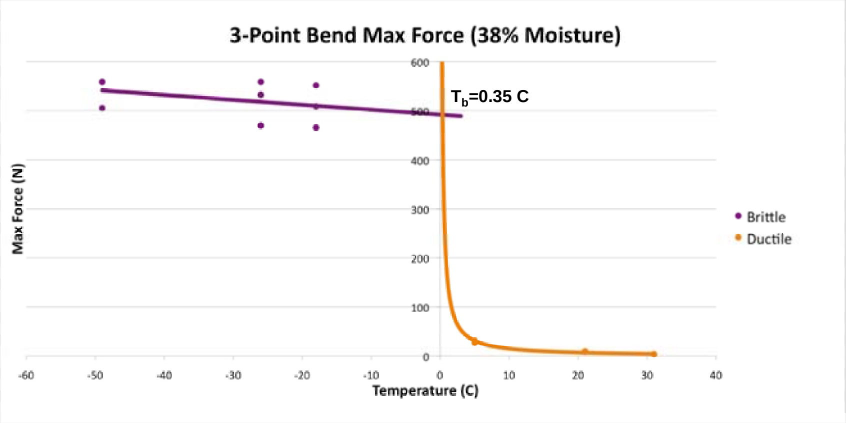


3-Point Bend

Three duplicates of small, uniform rectangles for each moisture content were equilibrated to one of six testing temperatures. The maximum breaking force of each moisture content of cheese was determined with the 3-point bend apparatus on a TAXT texture analyzer at each temperature. The measured maximum breaking forces for all of the samples were plotted over testing temperature. At the lower temperatures, the samples break in a brittle manner, but they yield before breaking when tested at higher temperatures (called ductility).

The intersection of the trend lines created by the lower brittle temperatures and the higher ductile temperatures determined the brittle-ductile temperature (T_b) for each cheese moisture content (Payne and Labuza 2005).

Results: Every moisture content exhibited a T_b greater than 0° and less than 1°C with no recognizable correlation to moisture content. It is clear from the DSC results (below left) that the melting of solid water at this temperature masks any distinctive signs of T_g. More samples will be tested at and near 0° to make further conclusions.



Conclusion

Although it is evident that high moisture American process cheese flows more easily than low moisture American cheese, the overall high water content masks the signs of T_g in differential scanning calorimetry. More data is needed to determine the T_b from the 3-point bend test. This Schreiber, DSC, and 3-point bend evaluation of cheese moisture content will serve the food industry to better understand the rheology and physical chemistry of American process cheese, and will enable the development of a more desirable product.

References

Park, J., Rosenau, J. R., & Peleg, M. (1984). Comparison of four procedures of cheese meltability evaluation. *J Food Science*, 49(4), 1158-1170.

Payne, C. R., & Labuza, T. P. (2005). The brittle-ductile transition of an amorphous food system. *Drying Technology*, 23, 871-886.