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Density and Calorimetry Explorations of Medium Chain Monoglycerides

I spent this summer working with Professor Paul Harper studying the lipids monomyristin, monolaurin, monocaprin, and monocaprylin, which are identical except for the number of CH_2 groups in the lipid tail. Lipids such as these are used in foods as emulsifiers (making two liquids mix that otherwise would not) and in cosmetics as surfactants (lowering the surface tension between liquids). In the medical world, lipids are used to crystallize proteins and encapsulate drugs. There has also been speculation about the role of lipids in the function of anesthetics. For their current uses and potential applications, lipids are a worthy subject of study.

These lipids are amphiphilic, meaning that they exhibit both hydrophilic (water-loving, polar) and lipophilic (fat-loving, nonpolar) properties. Our lipids can be thought of as having two primary components: a hydrophilic head group comprising carbons, oxygens, and hydrogens, and a hydrophobic carbon chain tail saturated with hydrogens. As these lipids are heated, their tails tend to shorten and widen, and their head groups tend to grow. These characteristics lead the lipids to arrange themselves in various phases depending in part on temperature and water concentration. At low temperatures, for example, these lipids freeze into sheets, lipid bilayers, separated by channels of water. The head groups are located on both sides of the sheet in contact with the water, and the lipid tails are inside the sheet, shielded from water contact. These sheets are known as lamellar phases. At low temperatures the lipids within the bilayer are frozen in place (this is known as the L_C phase). As the temperature increases the lipids become free to rotate (the L_β phase), and then free to move about laterally within the bilayer (the L_α phase). As the lipids are further heated, the tails shorten and widen, encouraging the lipid to form curved structures rather than flat sheets. The lipid then forms complex lattice structures (cubic phases). Curvature properties of these phases are a fascinating area of inquiry in their own right. As the lipid is further heated, it forms straight tunnels, arranged hexagonally, which are occupied by water (the H_{II} phase).

We were primarily interested in exploring the transition behavior of our lipids from the L_α to the L_β phase. We wanted to know where these transitions occur and what was happening within the lipids before, after, and during these transitions. To investigate, we prepared samples of our lipids in excess water and placed the samples in a differential scanning calorimeter (DSC). We cycled the samples between two temperatures at different rates, from 0.01 to 0.2 $^oC/s$, choosing our temperature ranges so that we passed over the L_α to L_β transition temperature. The DSC recorded data of heat flow out of the lipid sample. Generally, heat flow is constant as we move between temperatures. However, over certain temperature ranges, lots of heat must flow into or out of the lipid to change its temperature, indicating a phase transition. For monomyristin, monolaurin, and monocaprin, we found the following L_α to L_β transition temperatures: 35.8 ^oC, 17.2 ^oC, and -7.8 ^oC, respectively. We were able to analyze the transition temperatures, enthalpy changes, and transition widths. We could then study these traits as a function of ramp rate, in order to glean information about how the phase transition occurs. Since our lipids are all identical except for the number of CH_2 groups in the tail, we also studied how the tail length impacts phase behavior; the longer the tail, the higher the L_α to L_β transition temperature.

This research benefitted me in four key ways. First, I learned concepts and skills. In working on this project I learned a lot about biophysics, about phase transitions, and about lipid behavior. I also learned about instrumentation, including differential scanning calorimetry, polarized light microscopy, and x-ray diffraction. Second, I learned method and approach. I learned not only the minutiae of my project, but also the larger framework of how researchers approach questions and problems. Third, I learned communication and presentation. This research project has provided me the opportunity to write a scientific paper, and in the process, to learn how one writes a scientific paper. Last, and perhaps most important, I became more familiar with what research entails. This has left me better equipped to decide whether or not research is work I would like to be involved in long-term.