Get Wet Report

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MCEN 5151: Flow Visualization

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I. Overview

As the first major assignment for MCEN 5151: Flow Visualization, the purpose of this assignment was to gain experience with creating a fluids phenomenon and determining the best method for visualizing it, and to gain further knowledge of photographic techniques and camera settings. For this assignment, I chose to make caramel and document each stage of the process. Making caramel is an interesting example of home chemistry, with some significant chemical reactions taking place. While planning this assignment, I initially expected that my final image would be one taken just after the addition of butter. In previous experience, this led to the formation of many interesting bubbles. However, it was more difficult to take good photographs while actively cooking than I expected. My final image is one taken after all ingredients have been added and completely mixed and the final product has been transferred to a secondary glass to cool to room temperature. This temperature shift led to some interesting occurrences at the surface of the caramel, as some of the butter fats began to slightly separate from the caramel itself.

II. Experimental Set Up

I chose to make caramel using the dry method, which involves melting pure sugar on the stove and then adding the additional ingredients once the sugar has been fully dissolved. This is a relatively simple recipe, with only four ingredients: sugar, butter, heavy cream, and salt. I used a recipe from Sally's Baking Addiction, an online blog and recipe database.

Figures 1-3: Caramel stages.

To make caramel, first sugar is added to a pan on medium heat and melted until all the sugar is fully dissolved. This is shown above in Figure 1. Next, cubes of butter are added to the pot while stirring, as shown in Figure 2. After this, heavy cream is added as shown in Figure 3. The addition of each ingredient causes many bubbles to form due to the temperature differential and the chemical reaction with the new materials.

III. Fluid Dynamics

a. Chemical Reactions

The process of making caramel includes many different chemical reactions that lead to the specific chemical properties of the finished product. First, the process of caramelization occurs when heat is added to sugar. This is a complex reaction that can happen in different ways. This reaction first involves reordering among the sugars through enolization. The sugar will then dehydrate and lose water molecules. After this, many different molecules are formed which gives caramel its unique flavor and scent (Food Crumbles 2012). Golon and Kuhnert analyzed the chemical composition of caramel and identified the 40 most common molecules found in caramel formed from fructose, glucose, and sucrose. The best characterized is diacetyl, which is associated with a butterscotch flavor. Another prominent reaction that occurs is the Maillard reaction, which occurs at high temperatures between amino acids and reducing sugar. This reaction occurs during most cooking processes and is what leads to some of the brown coloring of the caramel (Tamanna and Mahmood, 2015). For this type of caramel making, this reaction occurs after the addition of the butter and the heavy cream. These reactions change the structure and the properties of the caramel, such as increasing the viscosity, which influences how it flows.

b. Emulsion and Temperature Change

An emulsion is a mixture of multiple liquids that are usually considered immiscible. This mixture takes on a homogenous microstructure at the macro level and a heterogeneous microstructure at the micro level (David and Akhondi, 2023). Butter, composed of liquid oils, fat molecules, and water, is considered a water-in-oil emulsion where the oil is considered the continuous phase with water the dispersed phase. When making caramel, cold butter is used because it increases the melting time of the butter, which reduces the chance of an immediate and drastic temperature change that could break the emulsion between the water and the fat.

The final image was taken immediately after the caramel was poured from the hot pot where it was made into a room temperature glass to cool. This temperature change caused some of the oil to separate from the emulsion and rise to the surface of the caramel. As this was not a drastic temperature shift, most of the fat remained in the emulsion creating a relatively uniform composition within the rest of the caramel.

IV. Visualization and Photographic Techniques

I took this image in my brightly lit kitchen mid-afternoon. I used a combination of indirect natural light coming from my shaded window, and indirect artificial light coming from the overhead lights. To prevent excessive glare from the overhead lights on the surface of the caramel, I used tissue paper to diffuse the light.

This image was taken on a Nikon D3200 DSLR camera using a macro lens with a fixed focal length of 40 mm. The use of a macro lens allowed me to get very close to the surface of the caramel in order to capture the small oil droplets in greater detail. I held the camera about 5 inches from the surface of the caramel and used manual focus. The exposure was set to 1/60, the aperture to f/3.2, and the ISO to 1796.

Figure 4: Original, unedited image.

The original image, shown above in Figure 4, displays a significantly larger portion of the surface of the caramel than shown in the final image. I cropped the image in order to better direct the viewer's eye to the individual oil droplets, which are relatively small in the original image. The original image has dimensions of 6016 x 4000 pixels, while the edited image has dimensions of 1200 x 797 pixels. Other than cropping, I didn't add many additional edits to the image other than slightly increasing the contrast and saturation.

V. Image Conclusions

Overall, I am happy with this image. I think it shows an interesting stage in caramel making that is not usually focused on unless something goes wrong. Additionally, this was not something that I had even noticed during past experience with caramel making so it was interesting to take the chance to look closer at each step and notice what was happening. I think that this image clearly displays how the fat separated from the caramel to sit on the surface.

However, I think that I could have improved the lighting for this image. The original image shows a large light reflection in the upper right corner. In my edited picture, I cropped the image so that only a slight color gradient was visible. While I do think that this color gradient added to my image and helped improve the visual interest of an otherwise monochromatic image, I feel that a better lighting source would have allowed for better focus on the individual fat droplets.

VI. References

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