good descriptive title

The Mouthfeel of Ricotta Cheese: The Effect of Temperature, Amount of Acid, and Fat Content on the Elasticity of Ricotta Cheese

abstract summarizing the project and results in 100-200 words. The exact % and temps are too detailed and could be excluded

Abstract: This project explores why ricotta cheese is sometimes soft and creamy and sometimes hard and granular, a culinary dilemma posed by Chef Jason Bond. This project investigates various factors that affect the mouthfeel of ricotta cheese and aims to determine the ideal conditions for making ricotta cheese. We test the effect of temperature at which acid is added (65°C, 75°C, 85°C, 95°C, 100°C), percent by volume of acid (1.05%, 1.25%, 1.53%, 1.66%, 1.87%, 2.03%), and the fat content of milk (fat free, soy milk, 1%, whole, heavy cream) on the elasticity of ricotta cheese, as measured by a rheometer. By manipulating the factors described above, we hope to find a scientific explanation for the various factors that affect the mouthfeel of ricotta cheese. Results showed that increasing the maximum temperature at which the milk is heated, increasing the amount of acid, and decreasing the fat content of milk all increase the resulting elasticity of the cheese.

culinary relevance

Motivation: The concept of denaturing proteins in milk first arose when we prepared mato cheese in the class laboratory. We noticed that each group made a different cheese despite following the same recipe indicating how sensitive the physical properties of cheese were. This inspired us to further examine how modifying the materials or procedure affected the end cheese product. The questions posed by Chef Jason Bond about ricotta cheese were expanded upon to include various factors that could potentially change the mouthfeel of the cheese. Mouthfeel, an important focus in the culinary world, refers to a food's physical and chemical interaction in the mouth and is an important feature in food rheology. The factors affecting the elasticity of ricotta are of greater importance to the eating experience due to the mild flavor of the cheese. From a scientific perspective, quantitative measurements would add to our conceptual understanding of how casein micelles in milk are affected by acid under varying conditions. The effects of one parameter were isolated by controlling the other factors affecting the cheese product and measuring how the rigidity through the elasticity modulus of the cheese changed. This provides a source of reasonable data on the texture of the cheese and prompts us to examine culinary observations through a scientific lens.

scientific relevance

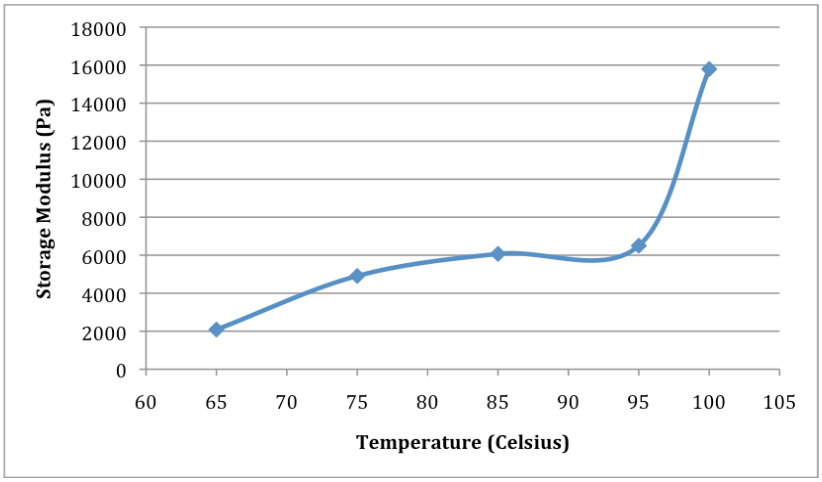
Materials & Methods: First, we heated 2 cups of milk in a pot on a hot plate until desired temperature is reached. When the desired end temperature has been reached, we gradually whisked in the distilled vinegar. Next, we let the cheese sit for 5-10 minutes before straining it with cheesecloth. To test each of the three factors, we held the other two factors constant while manipulating the third factor. The control conditions were heating whole milk to 85C and adding 7.4 mL of acid. To test temperature, we kept the fat content and acid constant, but brought the milk to 65°C, 75°C, 85°C, 95°C, and 100°C. To test the percent volume of acid, we held the fat content and temperature constant, and added varying amounts of acid (5 ml, 6 ml, 7.4 ml, 8 ml, 9 ml, and 10 ml of distilled vinegar). We calculated the percent by volume of acid for each amount of acid to yield 1.05%, 1.25%, 1.53%, 1.66%, 1.87%, 2.03%. Lastly, to test fat content, we replace the whole milk (3.25% fat) with fat-free milk (0% fat), skim milk (1%), and soy milk. We examined the ricotta samples under digital microscope for qualitative analysis. Using the Ares-G2 rheometer, we conducted two tests of elasticity: a frequency sweep (100 to 1 radians/second at 5 points per decade and 1% strain) and a strain sweep (1 radian/second, strain 1 to 100%, 5 points per decade), both at a controlled temperature. For angular frequency, the rheometer changes the speed at which the top plate of the rheometer is rotated. For oscillation strain, the rheometer changes the amplitude the bottom plate is rotated.

material and methods are described in detail. All concentrations and temperatures are given. the recipe/protocol is c the group has used advanced equipment. The fact that they show that they have talked to the course

Results and Discussion: The computer output of the rheometer provided measurements of the storage modulus and loss modulus with respect to the angular frequency and oscillation strain and stress. The storage modulus (G') is a measurement of how much energy is stored in the material, a proxy for elasticity. The loss modulus (G") is a measurement of how much energy is lost through the material, a proxy for viscosity. Appendices A-C provide the graphs of G' vs. the full range of frequencies for fat content, temperature, and acid. For visualization purposes, we chose to display G' vs. our independent variable holding frequency at 63.1 rad/s, a frequency where the changes in elasticity are relatively flat. Our results are shown in Figures 1-3.

Temperature:

Figure 1. Effect of Temperature on Storage Modulus

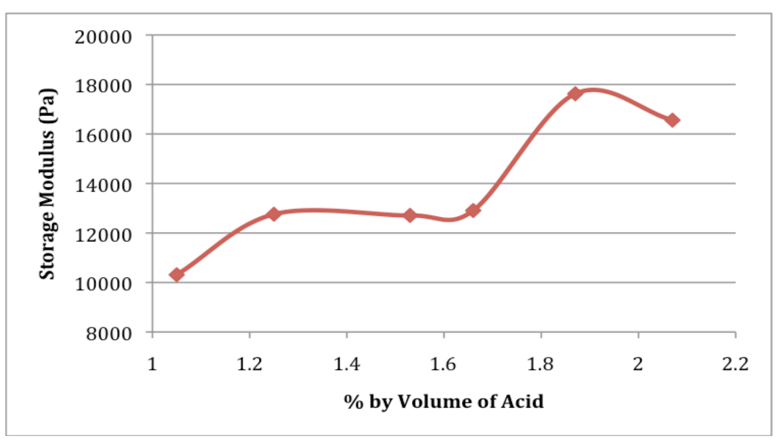


Holding frequency constant, as temperature increased, the storage modulus of the cheese samples increased, as shown in Figure 1. The drastic change in G' from 6499.3 Pa for the 95°C sample to 15795.1 Pa for the 100°C is most likely attributed to the fact that 100°C is the boiling point of milk since at this point, a phase transition occurs and molecules are moving more rapidly. Temperature affects the curdling of milk because heat causes protein denaturation in milk. Higher temperature (a faster movement of molecules) speeds the rate of reaction and allows for more interactions between the casein micelles and H+ ions. Since H+ ions reduce the negative charge on the surface of the casein micelles, preventing the micelles from repelling each other and lowering the energy barrier for micelles to coagulate. The increased interaction of H+ ions and casein allows the micelles to come closer together, forming a tighter network. Therefore, the overall elasticity of the ricotta is greater. Additionally, higher temperatures decrease the moisture retention properties of the curd, resulting in a more rigid, elastic cheese. From a qualitative perspective, we noticed that the cheese prepared at the highest extreme temperatures had finer granules and was more rigid, while the cheese prepared at low temperatures was more moist and clumpy.

good discussion of what the data means

Percent By Volume of Acid:

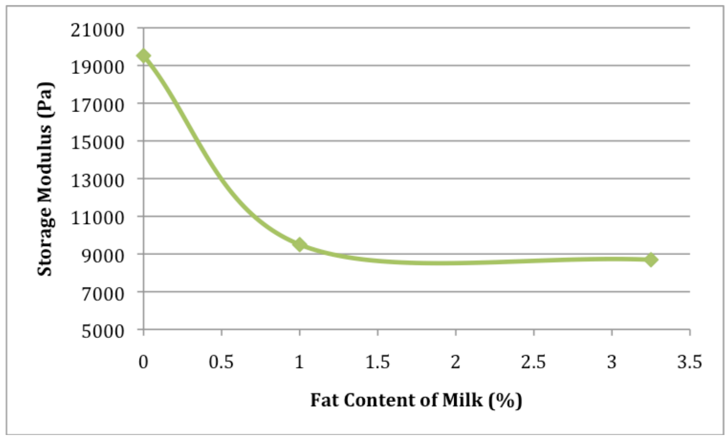
Figure 2. Effect of % by Volume of Acid on Storage Modulus



As we percent by volume of the acid in the milk in each trial, the elasticity of the cheese generally increased as well, as shown in Figure 2. There was one exception in that the 1.87% sample had higher storage modulus than the 2.03% sample. This difference, however, was quite small. Overall, increasing the amount of acid, or the number of H+ ions, increases the elasticity of the cheese. These H+ ions remove the negative charge barrier surrounding the casein micelles, preventing repulsion and enabling coagulation. Higher percent by volume by acid means there are more H+ ions present, increasing the number of proteins that can be denatured and allowing the proteins to come closer together to form a tighter network. In turn, this increases the elasticity of cheese because more casein micelles are able to aggregate and former bigger, flakier clumps. From our results, we can see that the storage modulus only experienced dramatic fluctuations to the percent by volume of acid when subject to extreme changes, which means it is not very sensitive to small alterations in the percent by volume.

Fat content:

Figure 3. Effect of % by Volume of Acid on Storage Modulus



the group varied several steps in the recipe: temp, acidity and fat content, and studied the effect on mouthfeel by looking at elasticity.

The results showed that as the fat content of the milk increased, the elasticity of the cheese decreased. Fat free milk had the highest storage modulus, 19522.1 Pa, compared to all of the milks at the same frequency. 1% milk and whole milk had similar storage moduli, with 1% milk having a slightly higher storage modulus. Soy milk had the lowest storage modulus of 2180.6 Pa, which was not shown in Figure 3. The presence of fat globules interferes with the coagulation of casein micelles. This was particularly evident when we tried to curdle heavy cream, which is 40% milkfat, and no curdling occurred. If fat globules account for more than 25%, the globule surface takes most of the casein out of the circulation and no casein curds form.[1] With higher fat content, more fat globules latch onto the casein, taking some of the casein out of circulation and creating a looser network of casein proteins. Therefore, a higher fat content actually decreases elasticity of ricotta cheese. The fat-free milk created very clumpy cheese while the skim and whole milk created a more standard texture. In soymilk, soy proteins, rather than casein micelles coagulate, forming tofu rather than ricotta cheese. Due to a different chemical structure, soy proteins form a looser protein network and have the lowest elasticity.

succinct conclusion of the findings

some ideas for further things that could be investigated

Conclusion and Future Directions: This project showed that increasing the maximum temperature at which the milk is heated, increasing the presences of acid in the milk, and decreasing the fat content of milk all resulted in an increase of the cheese's elasticity or rigidity. During the experiment process, particular issues arose that may provide future directions for others interested in exploring the mouthfeel of ricotta cheese. One could investigate how other factors would effect the elasticity or the ricotta cheese, such as the rate at which vinegar was added and adding salt at different times to the ricotta prior to straining. Although we tested the effect of soy milk and other different fat contents of milk on the cheese's elasticity, another question to explore would be whether a combination of different types of milk would effect elasticity, such as using both heavy cream and milk.

Acknowledgements: A special thanks to Chef Jason Bond for his inspiration in exploring ricotta cheese and its mouthfeel, Naveen and Lulu for their help with the rheometer, Dilani for ensuring our weekly progress, Professor Weitz for encouraging us to integrate concrete scientific ideas into our culinary project, and Pia and Heloise for helping us brainstorm initial project ideas.

[1] Harold McGee. *On Food and Cooking.* New York: Scribner, 1984. Pg. 29