Podcast Interview - Daniel Hodgson

PNAS: Welcome to Science Sessions. I'm Paul Gabrielsen. Chocolate goes through a long journey before it becomes the smooth, shiny, sweet product we see in candy bars. One of the steps in that process is called conching. Solid ingredients, including cocoa powder, sugar, and fat, go into mixing vats that stir and pummel the ingredients until they become flowing, molten chocolate. Daniel Hodgson, of the University of Edinburgh, says that this process has application far beyond candy making. Solids and liquids are mixed in a wide range of industrial processes, and understanding the physics of conching helps inform other processes as well. In a recent PNAS paper, Hodgson and his colleagues broke down the small-scale physics that make chocolate, as we know it, possible. He explains how he came on board with the research, which was partially funded by Mars Chocolate UK.

Hodgson: I certainly am a chocolate fan. So, at the time this work started, I was actually studying for my PhD in Edinburgh. I was working on a considerably less tasty system, but in some respects had similar attributes; I was mixing solid components and liquid components and seeing how they behaved. So my colleague, Elena Blanco, and my PhD supervisor, Wilson Poon, they were looking at the conching process in collaboration with researchers in New York. There was also always very nice smells coming out of the lab. So, following my PhD there was an opportunity to continue some of this work and get involved, so I jumped at the chance to do that.

PNAS: One of the important concepts in the conching process is called "jamming." Hodgson explains.

Hodgson: Jamming is essentially the point at which an assembly of particles can no longer flow past each other. So, in this case the solid particles are lumps of sucrose and other solid chocolate components, but you could imagine a crowd of people trying to leave a busy venue and getting jammed, or coffee grounds down the sink. It's essentially where you have individual solid components and you can attempt to pack them more or make them move past each other and they form a state where they can't flow any longer and that's what we term as jamming. It's this point where the system ceases to flow because of the chains and the packing of the particle components suspended in it.

PNAS: To study conching, Hodgson and his colleagues mixed up small batches of chocolate in what's called a planetary mixer, in which the mixing blade rotates on its own axis as it orbits around the outside of the bowl. A mixture of solid sucrose, cocoa and milk was mixed with sunflower oil and lecithin in two conching steps. Hodgson describes what they found.

Hodgson: We use a vigorous mixing action to perform the conch. Our understanding is that this starts to break up aggregates and clusters of particles within the system so it can break them up, round them, or smooth them; essentially allow them to flow better past each other. Initially the system is jammed such that it can't flow. What happens is that the mixing action breaks this up into granules, which is what you observe during the initial stages of the conch. So these are individual jammed lumps of material made up of the solid and liquid. These granules grow with time as the conch progresses and as the particles start to pack more efficiently. What we end up with is this single, cohesive state which incorporates all the material in the conch. What we do to that is add the lecithin, which is a friction reducing substance. What this does is allow the particles to pack significantly better, which has the macroscopic effect of fluidizing the whole system and transforming from this kind of matte, non-flowing substance into the smooth, flowing chocolate which we all recognize.

PNAS: There's a connection, he says, between chocolate conching and the science trick involving running across a mixture of cornstarch and water. As a person runs on the mixture, it's stiff enough to support their weight. But if they stop running, they sink as if in a liquid. Hodgson describes one of the physical phenomena attributed to this effect.

Hodgson: So, this behavior is known as shear thickening. When you apply low pressure, when you're simply standing on it, for instance, the particles in the suspension can move past each other, they can slide or roll past each other, however when you jump on it or hit it or punch it as you often do, this pushes particles into frictional contact which means that they can no longer slide past each other. What this can do is to cause the system to jam and is then able to support the runner's weight. In chocolate, because of our understanding of how the system flows, we know that the particles are always in frictional contact. So we can use our understanding from shear thickening to interpret the second stage of the conch, which is the addition of this friction-reducing substance lecithin.

PNAS: Hodgson says that an understanding of how conching gives chocolate its unique character applies to an entire sector of industrial manufacturing. Some of the insights gained may improve the efficiency of the process.

Hodgson: The conching process and more generally the breaking up of aggregates in any system is an energy-intensive process, which we've shown in the paper. Our hope is, one of the applications of this work might be that by shedding light on the physics of how the conching process works, it may be possible to optimize the production of these powder-liquid formulations, including chocolate, also including concrete, things like that, so that the amount of energy perhaps is reduced.

PNAS: After this study, Hodgson says he looks at chocolate bars a little differently.

Hodgson: I suppose it gives me a certain amount of satisfaction to be able to think about how it was made and to look at the ingredients and to understand what role they're playing, the functional role in, certainly, the mechanics of how it feels in your mouth or flows, and that's certainly a satisfying thing.

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