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When egg meets cornstarch aqueous solution: ooblecks demonstrate thixotropic properties

Chiung-Lan Wang

The Chemical Educational Resource Center (CERC) of Taiwan
No.50, Jianguo 3rd Rd., Sanmin District, Kaohsiung City 807, Taiwan
wang7581@ms22.hinet.net

Abstract
This experiment demonstrates the phenomena created when different types of eggs collide with cornstarch aqueous solutions. The eggs used in this experiment include raw eggs, unshelled eggs, and century eggs (*i.e.*, preserved eggs). The cornstarch solution is formed by mixing cornstarch with water (1 part water to 1.5–2 parts cornstarch). This non-Newtonian fluid is called an "oobleck" or "ooze". When an egg collides with the oobleck, it suddenly depresses the contact surface. Like billions of little springs, the surface compresses and stretches, mitigating the force of impact and causing the object to bounce off without damage. The intermolecular interactions and van der Waals forces (such as dipole–dipole forces, dipole–induced dipole forces, and London dispersion forces) can be recorded and watched with rapid photography.

Keywords: non-Newtonian fluid, oobleck, egg, van der Waals force

Introduction

At a stand at a fair, there was a vendor who challenged the audience, “Whoever can break an egg by throwing it into this basin filled with cornstarch slurry will win drinks and candy.” This challenge attracted a group of people, and each of them tried. No matter how hard they threw the egg, though, no one could break it. Finally, a basketball club vice-captain threw an egg so hard that it bounced out of the basin, and it broke when it hit the ground. This sparked the curiosity of students, thus inspiring the following series of experiments.

Principle

Oobleck [1], a kind of non-Newtonian fluid [2], becomes a fluid when agitated and returns to a solid or semi-solid state when allowed to stand. If one slowly squeezes an oobleck, it will flow between the fingers like a liquid; if the substance falls onto the floor, the force of gravity on the oobleck will cause it to behave as a solid. Thus the oobleck demonstrates thixotropic [3] properties. The instant contact between the surface of the materials generates intermolecular van der Waals forces.

Materials

A plastic basin (size: 60.5 cm x 48 cm x 16 cm), 5.0 kg cornstarch [4], two raw eggs, a century egg [5], water, 1.0 M hydrochloric acid, and a 250 mL beaker. The century egg (called *pidan* in Mandarin Chinese) is a duck, chicken, or quail egg that has been preserved in a mixture of clay, ash, salt, quicklime, and rice hulls for several weeks to several months.

Experimental Procedure

1. Mix cornstarch with water (1 part water to 1.5–2 parts cornstarch) to create an oobleck on the plate, about six centimeters thick.
2. Prepare an unshelled egg by soaking a raw egg in 150 mL 1.0 M hydrochloric acid in a 250 mL beaker for about an hour (see Figure 1). This will dissolve the egg's outer shell and leave only the membrane.

Figure 1. Preparation of an unshelled egg by soaking an egg in hydrochloric acid.

3. Drop a raw egg onto the oobleck (see Figure 2) and observe the egg bounce off the oobleck.

Figure 2. The egg dropped onto the oobleck bounces without breaking.

4. Drop the unshelled egg from Step 2 onto the oobleck and observe the unshelled bounce off the oobleck.
5. Drop the century egg onto the oobleck (see Figure 3) and observe the century egg bounce off the oobleck.

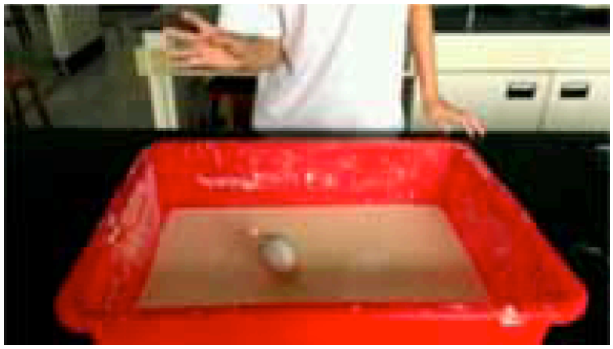

Figure 3. The century egg dropped onto the oobleck does not break and can bounce.

6. Take a wad of oobleck and drop it onto the oobleck in the plastic basin. Observe the bouncing phenomenon.

Results

When a raw egg, unshelled egg, or century egg is dropped onto an oobleck, the egg will bounce off undamaged. This phenomenon can be observed using rapid photography and uploaded to YouTube [6].

Discussion

1. A raw egg dropped onto an oobleck will bounce off without breaking (see Figure 2). A raw egg is covered with a protective eggshell, and the main component of the shell of the egg is calcium carbonate (an ionic compound). Cornstarch has high amylose content, the main component of straight chain α-glucose polymers with spring-like helical structure (polar polymer molecules, including hydrogen bonds and polyether linkage). The raw egg tilts the surface of the oobleck upon impact and thus bounces. The forces at work between the surfaces are mainly dipole–induced dipole forces.
2. An unshelled egg dropped onto an oobleck will also bounce off undamaged. The unshelled egg is protected by a membrane whose main ingredient is protein (polar polymer molecules containing amide bonds and hydrogen bonds). The forces at work between the surfaces are mainly dipole-dipole and hydrogen bonding forces.
3. A century egg dropped onto an oobleck will bounce off, only this time even higher (see Figure 3). The shell of a century egg is comprised primarily of a short-chain protein (polar molecule aggregation materials, including amide bond, hydrogen bond). The forces at work between the surfaces are mainly dipole–dipole and hydrogen bonding forces.
4. Dropping a wad of oobleck onto an oobleck surfaces produces bouncing followed by fusing of the wad into the solution in the basin. Oobleck is made of a cornstarch suspension, polyvinyl alcohol–based glue and borax.

5. These types of materials could be used in car bumpers. Car bumpers are generally made of chrome plated hard shells. If these were replaced with short-chain polymer materials with hydrogen-bonding short-chain amide bonds, vehicles could park more easily in tight spots. In the event of a collision, there would be no damage to the vehicle or structure. If the vehicle were to be violently hit, the polymer bumper would automatically "bounce," thus preventing damages and casualties.

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References

[1] Url = http://www.instructables.com/id/Oobleck/.
[2] Url = http://en.wikipedia.org/wiki/Non-Newtonian_fluid.
[3] Url = http://en.wikipedia.org/wiki/Thixotropy.
[4] Url = http://en.wikipedia.org/wiki/Corn_starch.
[5] Url = http://en.wikipedia.org/wiki/Century_egg.
[6] See, for example, the video at url = http://youtu.be/EJlXfvnMeG0.